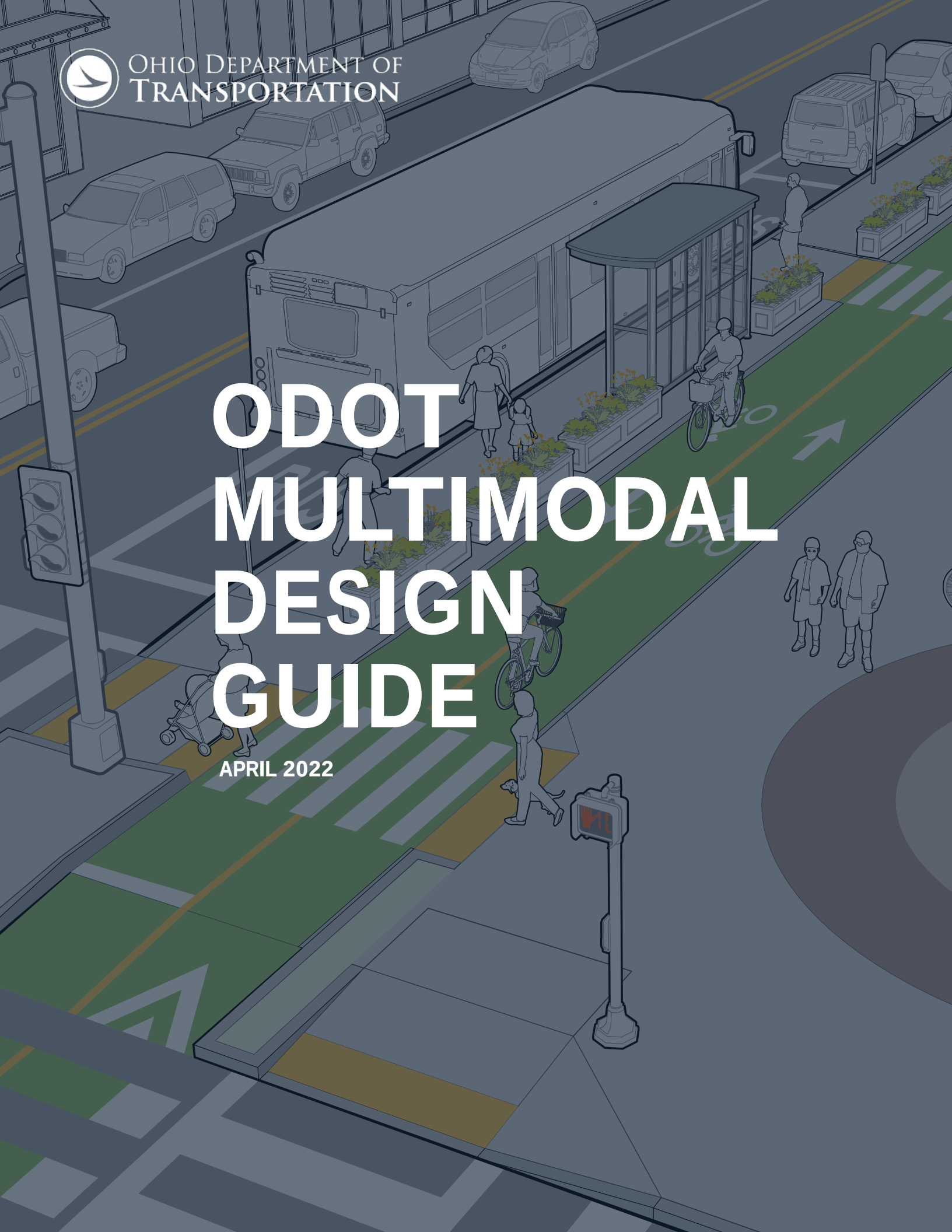

OHIO DEPARTMENT OF TRANSPORTATION

ODOT MULTIMODAL DESIGN GUIDE

APRIL 2022

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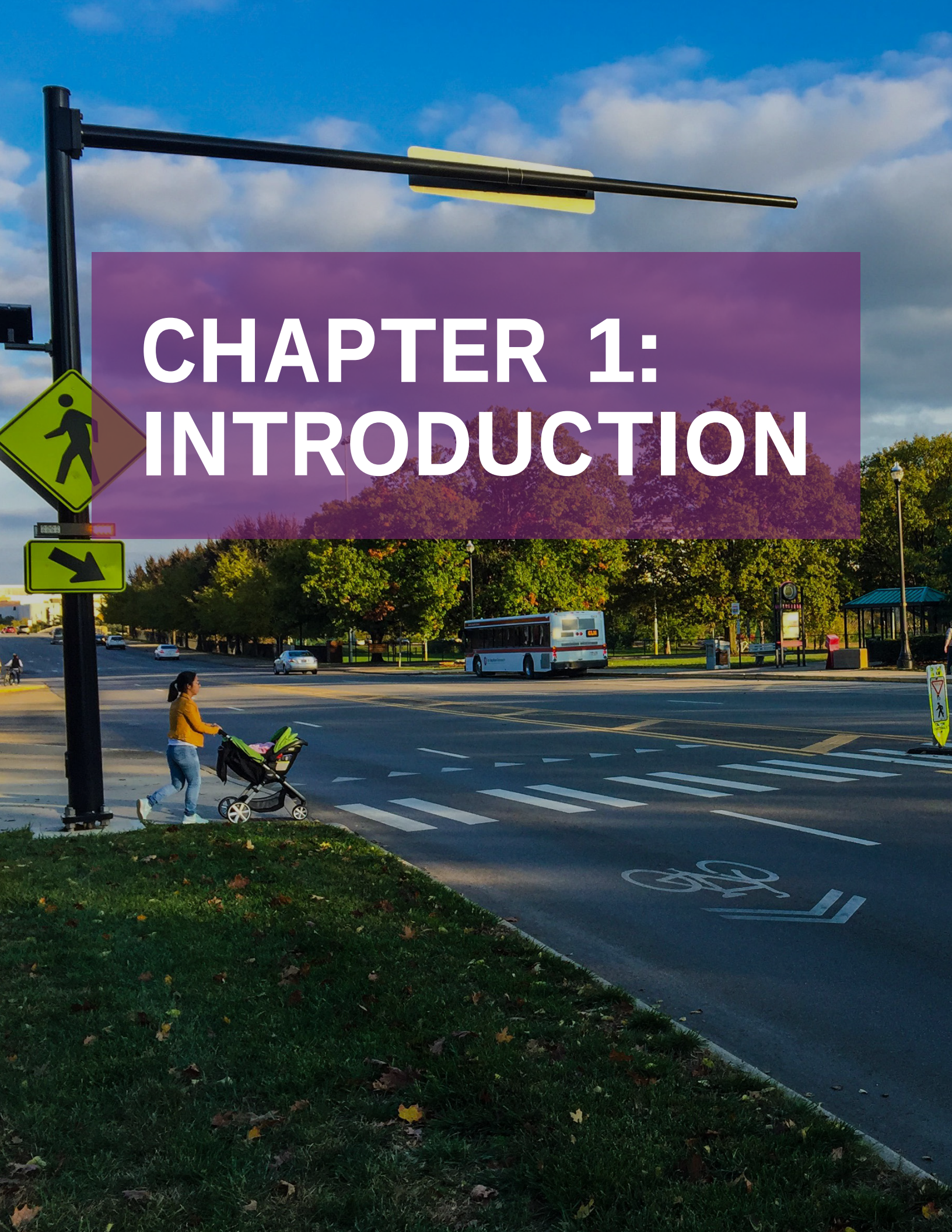

CHAPTER 1: INTRODUCTION

Chapter 1: Introduction

1.1 Purpose of the Multimodal Design Guide

This Multimodal Design Guide, hereafter referred to as the MDG, serves as a source for planners and designers implementing pedestrian and bicycle facilities in ODOT right-of-way and as part of the Local Let Process. By providing comprehensive state-of-the-practice design guidance, the MDG aligns with ODOT's current vision, mission, and goals related to walking and bicycling. It advances the Department's overall mission of improving safety across the state; it aligns with ODOT's Statewide Bicycle and Pedestrian Plan's vision that walking and biking will be a safe, convenient, and accessible transportation options for everyone; and it supports the Strategic Highway Safety Plan's goal of achieving zero deaths on Ohio's roadways.

Communities (Local Public Agencies) can apply this guidance to their local and regional transportation networks to create uniformity across the state's multimodal transportation system. The MDG will also be used by ODOT to review local agency designs for federally funded projects. The MDG can also be a reference for community members, advocates, elected officials, and other stakeholders interested in advancing multimodal transportation design practices in Ohio.

1.2 Scope, Context, and Authority of the MDG

1.2.1. Scope

The MDG provides information for planners, designers, and engineers to develop the physical infrastructure necessary to support walking and bicycling for people of all ages and abilities. This design guide includes information on developing connected bicycle and pedestrian networks and addresses topics such as comfort and safety of facilities in different contexts. This guide addresses safety-related issues, especially for interactions between vulnerable road users (e.g., pedestrians and bicyclists) and motor vehicles. The MDG does not address education, encouragement, evaluation, or enforcement programs to support walking and bicycling. The *Ohio Manual of Uniform Traffic Control Devices* (OMUTCD) is to be used in conjunction with this guide. The MDG is not intended to be a detailed design or traffic engineering manual that could supersede the need for application of sound principles by knowledgeable design or traffic engineering professionals.

1.2.2. Relationship with Other References

ODOT discusses pedestrian and bicycle design guidance across many manuals and other documents. The MDG was created to provide a comprehensive guide for the development of bicycle and pedestrian transportation facilities. Additional documents that provide multimodal design guidance include:

Table 1-1: Existing multimodal transportation manuals at ODOT

Manual	Description	Relevant Sections
Ohio Traffic Engineering Manual (TEM)	The *Traffic Engineering Manual* is ODOT's primary manual for traffic engineering policies, guidelines, standards, and best practices. All ODOT traffic engineering information is found or cross-referenced in the TEM. The TEM contains traffic engineering guidance for roadways, including pedestrian and bicycle facilities, on all ODOT-maintained roads.	• Pedestrian control at intersections is covered in Sections 404: Pedestrian Control Features and 442-18: Plan notes for pedestrian signal heads. • In Section 420-5.3, detector loops are suggested to allow bicycles and motorcycles to be detected at intersections. • Temporary pedestrian (Sections 603-2, 640-25, 641-28) and bicyclist (Sections 606-11, 670-2) accommodations are outlined in Part 6, Temporary Traffic Control. • Part 9 contains engineering documentation for bicycle facilities.
Location and Design (L&D) Manual, Volume 1	The Ohio *L&D Manual, Volume 1* is a synthesis of AASHTO's geometric and roadside design guidance applicable to the state of Ohio.	• 100 Design Controls and Exceptions • 200 Horizontal and Vertical Design • 300 Cross Section Design • 400 Intersection Design • 500 Interchange Design • 600 Roadside Design • 700 Multi-Modal Considerations • 800 Access Control, R/W Use Permits and Drive Design • 900 Roadside Safety Landscape Guidelines • 1000 Performance Based Project Development
Bridge Design Manual	The *Bridge Design Manual* (BDM) is published by the Office of Structural Engineering and is intended to promote uniform, safe, and sound bridge design around the state.	• 303.2 Pedestrian And Bikeway Bridges • 306.5 Type of slope protection required when adjacent to pedestrian traffic • 309.4 Bridge Railing - refers to areas of the AASHTO LRFD code for pedestrian and bike railing that is protected from vehicular impacts. • 309.5 Various fencing configurations • 309.8 Sidewalks & Shared Use Facility • 310.7 Bicycle Bridges • 310.8 Pedestrian Bridges • 602.2 Pedestrian loading • 611.5 Vandal fencing on bridges with pedestrians • 915 Analysis Of Bridges With Sidewalks • 925.2 Pedestrian loading for general load rating • 1002.1 ODOT's supplement to the LRFD code related to pedestrian traffic protection • 1002.2 ODOT's supplement to the LRFD code related to additional vertical clearance for pedestrian overpasses • 1003.8 ODOT's supplement to the LRFD code related to pedestrian bridge loading

Manual	Description	Relevant Sections
Ohio Manual of Uniform Traffic Control Devices (OMUTCD)	The OMUTCD establishes a uniform system of traffic control devices that are compliant with the FHWA's national MUTCD. The manual covers standards for the design and use of traffic control devices on any street, highway, bikeway or private road open to public travel in Ohio.	• Part 2: Signs. Contains information and design specifications on signage, including signage related to pedestrians. • Part 3: Pavement Markings. Contains the general pavement markings info including for crosswalks. • Part 4: Traffic Signals. Contains pedestrian info at signals. • Part 6: Temporary Traffic Control. Contains information and design specifications for maintaining pedestrian facilities during construction. • Part 7: Traffic Controls for School Areas. Contains information and design specifications for establishing safe school walking routes and school crossings; including signs, pavement markings, and crosswalk supervision by crossing guards. • Part 9: Traffic Controls for Bicycle Facilities. Contains information and design specifications on signage, street markings, and signals for bikeways and shared use facilities.
ODOT State Highway Access Management Manual (SHAMM)	Establishes procedures and standards for accesses on state facilities.	• Section 4: Driveways. Contains information about driveway spacing and sight distance

In addition to those noted above, several other ODOT documents incorporate pedestrian and bicycle design guidance, including the Ohio *Temporary Traffic Control Manual*, the *Sign Designs and Markings Manual*, and *Standard Construction Drawings*. All designers should use the MDG in conjunction with the current versions of these references.

The MDG's primary function within ODOT's family of manuals and design standards is to update and consolidate bicycle and pedestrian transportation guidance across the Department. The MDG also takes into account a broader framework of national design guidance that informs pedestrian and bicycle projects. There are several national sources of multimodal transportation design standards, including:

- AASHTO *Guide for the Development of Bicycle Facilities*
- AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities
- FHWA *Small Town and Rural Multimodal Networks*
- FHWA *Bikeway Selection Guide*
- FHWA *Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts*
- FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossings*
- FHWA *Accessible Shared Streets*

- NACTO *Urban Bikeway Design Guide*
- NACTO *Urban Street Design Guide*
- NACTO *Transit Design Guide*
- NCHRP *Crossing Solutions at Roundabouts and Channelized Turn lanes for Pedestrians with Vision Disabilities: A Guidebook (2017)*
- ITE *Implementing Context Sensitive Design on Multimodal Thoroughfares*
- ADA *Accessibility Guidelines (ADAAG)*
- U.S. Access Board *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG)*

This Guide includes treatments that have FHWA interim approval to represent the state of the practice accurately.

The FHWA periodically issues Interim Approvals (IAs) to allow the use of new traffic control devices between updates of the MUTCD. Agencies that desire to use these treatments must request specific approval from the FHWA. ODOT has received approved requests for statewide approval from FHWA that apply to all jurisdictions in the state for some design treatments. Additionally, some cities have approved requests for IAs within their city boundaries. The MDG provides guidance for treatments that have been given Interim Approval status for city and/or statewide use. Traffic control devices that have IAs and/or require approval from FHWA are identified throughout this guide in grey boxes like this paragraph.

1.3 Use of Values in this Guide

It is important for users of this guide to understand that the selection of values for design dimensions can have a direct relationship to street user safety and comfort. In many instances, the use of constrained values does not account for a street user's perception of safety, and it is this perception of how safe a person *feels* that will affect how they choose to use or avoid a particular facility or street. In order to design safe multimodal facilities, with forgiveness and driver error in mind, pedestrian and bicycle facilities should be designed with the recommended values provided in this guide.

The MDG proposes consistent terminology to help with the design process. This use of consistent terms is not intended to supersede the need for design flexibility, context sensitivity, or engineering judgement. However, where deviations from the recommended values are proposed, those deviations should be based on an engineering study and the deviations properly documented.

1.3.1. Minimum Values

Minimum values are identified throughout this guide using the words "recommended" or "minimum." Minimum values may be presented as a single value or a range of values. The use of

these recommended values (typically larger values) should be used, where practical, to maximize the safety and comfort of pedestrians and bicyclists. Use of other values (typically smaller values) should only be used if and where it is not possible due to social, fiscal, and/or project constraints.

1.3.2. Constrained Values

Constrained values are explicitly identified using the word "constrained," "at least," or "not less than." The use of constrained values should not be considered a default value for pedestrian and/or bikeway design. The use of constrained values may result in tradeoffs with respect to pedestrian and bicyclist comfort and safety.

The words "in constrained conditions" are used to identify constrained values that are likely to degrade comfort and may degrade safety (for example, a separate bike lane width that is physically wide enough to accommodate a bicyclist, but not wide enough to permit another bicyclist to pass). In general, the use of constrained values should only be considered for limited distances, as an interim measure, at locations where low volumes of pedestrians or bicyclists are existing and anticipated, or where the value of providing the constrained width facility outweighs the option of providing no facility at all.

1.3.3. Maximum Values

Some design values in this guide are identified as "maximum," "no more than," "no greater than," or "not to exceed." These represent design values that should not be exceeded due to their potential to diminish the value of the treatment (e.g., sign or symbol placement frequency).

1.4 Definitions

Accessible – Describes a facility in the public right-of-way that complies with the Americans with Disabilities Act (ADA) and this guide.

Alteration – A change to a facility in the public right-of-way that affects or could affect pedestrian access, circulation, or use. Alterations include, but are not limited to, resurfacing, rehabilitation, reconstruction, historic restoration, or changes or rearrangement of structural parts or elements of a facility.

Accessible Pedestrian Signal – A device that communicates information about pedestrian signal timing in non-visual format(s) such as audible tones, speech messages, and/or vibrating surfaces.

Accessible Pedestrian Signal Detector – A device designated to assist the pedestrian who has vision, auditory, and/or physical disabilities in activating the pedestrian phase.

Bicycle Boulevard – Streets designed to prioritize bicycle traffic by minimizing motorized traffic volumes and operating speeds. They are also commonly referred to as neighborhood bikeways or greenways.

Bicycle Facilities – A general term denoting provisions to accommodate bicycling, including

bikeways, bicycle boulevards, bicycle detection, shared lane markings, signed bicycle routes, and wayfinding, in addition to parking and storage facilities.

Bicycle Route – A road, path, or facility designated for bicycle travel, sometimes using bicycle route signage, where space for bicyclists may or may not be distinct from motor vehicle traffic.

Bikeway – Any road, path, or facility intended for bicycle travel which designates space for bicyclists distinct from motor vehicle traffic. A bikeway does not include shared lanes, sidewalks, signed bicycle routes, or shared lanes with shared lane markings, but does include bicycle boulevards.

Blended Transition – A raised pedestrian crossing, depressed corner, or similar connection between the pedestrian access route at the level of the sidewalk and the level of the pedestrian crossing that has a grade of 5 percent or less.

Clear Space – (1) A space free of sight distance obstructions to allow motorists and bicyclists in motion to see each other and yield (or stop) accordingly as they approach intersections or driveways. (2) A space free of obstruction for pedestrian maneuverability complying with PROWAG Section R404.

Crosswalk – The pedestrian accessible route within a street used to cross a street or portion of a street. Further defined in the *Ohio Revised Code*, Section 4511.01(LL), as (1) that part of a roadway at intersections ordinarily included within the real or projected prolongation of property lines and curb lines or, in the absence of curbs, the edges of the traversable roadway; (2) any portion of a roadway at an intersection or elsewhere, distinctly indicated for pedestrian crossing by lines or other markings on the surface; (3) Notwithstanding definitions (1) and (2), there shall not be a crosswalk where local authorities have placed signs indicating no crossing.

Cross Slope – The grade that is perpendicular to the direction of pedestrian travel.

Curb Line – A line at the face of the curb that marks the transition between the curb and the gutter, street, or highway.

Curb Ramp – A ramp that cuts through or is built up to the curb. Curb ramp types can be perpendicular or parallel, or a combination of parallel, perpendicular, and diagonal ramps.

Detectable Warning Surface – A standardized truncated dome grid surface built in, or applied to, walking surfaces to indicate the boundary between a pedestrian route and a vehicular route where there is a curb ramp or blended transition, and at the edge of transit boarding platforms.

Directional Indicator – A traversable tactile surfaces comprised of raised bars that may be deployed parallel to the pedestrian path of travel to help pedestrians follow an accessible pathway or navigate a large open space. They may also be deployed across the pedestrian path of travel to provide guidance to pedestrians with disabilities regarding when to turn (e.g., to locate a mid-block curb ramp, bus island, or transit door).

Engineering Judgment – The evaluation of available pertinent information, and the application of appropriate principles, provisions, and practices as contained in design guides, for the purpose of deciding upon the applicability, design, operation, or installation of design elements and traffic

control devices. Engineering judgment shall be exercised by the designer through the application of procedures and criteria established by the engineer. Documentation of Engineering Judgment is recommended but not required.

First- and Last-mile Connections – A general term for pedestrian and bikeway facilities designed to help people access transit stops and stations.

Grade Separated Facilities – Facilities that support nonmotorized travel utilizing structures over or under traffic facilities, creating a separated pathway across a roadway.

Intersection – The area where two or more user travel paths meet. Further defined in the *Ohio Revised Code*, Section 4511.01(KK), as (1) The area embraced within the prolongation or connection of the lateral curb lines, or, if none, then the lateral boundary lines of the roadways of two highways which join one another at, or approximately at, right angles, or the area within which vehicles traveling upon different highways joining at any other angle may come in conflict; (2) Where a highway includes two roadways thirty ft. or more apart, then every crossing of each roadway of such divided highway by an intersecting highway shall be regarded as a separate intersection. If an intersecting highway also includes two roadways thirty ft. or more apart, then every crossing of two roadways of such highways shall be regarded as a separate intersection; (3) The junction of an alley with a street or highway, or with another alley, shall not constitute an intersection.

Landing – Part of a pedestrian accessible route or walkway that provides space for turning, pedestrian pushbutton accessing, or resting. Landings are typically level with a cross slope and grade of 1.56 percent maximum.

Major Street – The street normally carrying a higher volume of vehicular traffic.

Micromobility Device – A general term describing inline skates, roller skates, skateboards, kick scooters, electric scooters, self-balancing devices, or other small, low-speed, human- or electric-powered transportation devices.

Minor Street – The street normally carrying a lower volume of vehicular traffic.

Mutual Yielding – A general term describing the responsibility among motorists, bicyclists, and pedestrians to yield the right of way depending upon the timing of their arrival at an intersection or conflict point.

Pedestrian – A person on foot or in a wheelchair.

Pedestrian Access Route (PAR) – A continuous and unobstructed path of travel provided for pedestrians within or coinciding with sidewalks and walkways.

Pedestrian Curb Cut – A break or cut in the vertical curb to eliminate curb barriers. Pedestrian curb cuts are typically provided where sidewalk does not exist or the pedestrian access route is at the same elevation as the crossing and a curb separates the PAR from the crossing.

Physical Barrier – A physical object that prohibits pedestrian, bicyclist, or motorist movement. This could be a curb, guardrail, fence, street amenities such as benches or planters, etc.

Pushbutton – A button to activate a device or signal timing for pedestrians or bicyclists.

Pushbutton Information Message – A recorded message that can be actuated by pressing a pushbutton when the walk interval is not timing and that provides the name of the street that the crosswalk associated with that pushbutton crosses and can also provide other information about the intersection signalization or geometry.

Pushbutton Locator Tone – A repeating sound that informs approaching pedestrians that a pushbutton exists to actuate pedestrian timing or receive additional information and that enables pedestrians with vision disabilities to locate the pushbutton.

Ramp – A pedestrian pathway or access route with a slope greater than 5 percent. A ramp may or may not be part of a curb ramp.

Running Slope – Also known as longitudinal slope. The slope that is parallel to the direction of travel.

Pedestrian Facilities – A general term denoting provisions to accommodate or encourage walking. Pedestrian facilities include, but are not limited to, accessible routes, sidewalks, crosswalks, crossing islands and medians, traffic control features, curb ramps, bus stops and other loading areas, shared use paths, and stairs.

Separated Bike Lanes – A bicycle lane that is physically separated from motor vehicle traffic by vertical elements and a horizontal buffer. These are also sometimes referred to as protected bike lanes or cycle tracks.

Shared Lane – A roadway travel lane used by both motor vehicle travel and bicycle travel where no bicycle lane is designated.

Shared Street – A street where pedestrians, bicyclists, and motor vehicles mix in the same space.

Shared Use Path – Multiuse path designed primarily for use by bicyclists, pedestrians, and/or micromobility device users for transportation and recreation purposes. Shared use paths are physically separated from motor vehicle traffic by an open space or barrier. Shared use paths are sometimes referred to as paths.

Sidewalk – A walkway located along a roadway. Further defined in the *Ohio Revised Code*, Section 4511.01(FF), as that portion of a street between the curb lines, or the lateral lines of a roadway, and the adjacent property lines, intended for the use of pedestrians.

Vertical Surface Discontinuities – Vertical differences in elevation between two adjacent surfaces.

Vibrotactile Pedestrian Device – An accessible pedestrian signal feature that communicates, by touch, information about pedestrian timing using a vibrating surface.

Walkway – A general term used to describe a paved or improved area for use by pedestrians. Walkways include sidewalks, shared use paths, curb ramps, blended transitions, etc.

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CHAPTER 2: MULTIMODAL PLANNING AND DESIGN SCOPING PROCESS

Chapter 2: Multimodal Planning and Design Scoping Process

2.1 Introduction

ODOT supports the vision that walking and bicycling be safe, convenient, and accessible transportation options for everyone. To achieve this, the consideration, selection, and design of appropriate bicycle and pedestrian facilities is critically important.

This chapter discusses context-sensitive design and the need to plan and design projects that are sensitive to local circumstances and priorities. The tools, documents, and other ODOT resources needed to guide project development and scoping are discussed, as well as various multimodal planning approaches and analytical tools helpful for practitioners to make informed planning decisions. Additionally, this chapter can be used to evaluate facility feasibility and assess alternatives. A list of major planning tools and resources focused on bicycle and pedestrian transportation (active transportation) can be found on **ODOT's Active Transportation webpage**.

2.2 Bicycle and Pedestrian Policy and Guidance

The following policies and plans serve as the foundation for pedestrian and bicycle project planning and implementation.

2.2.1. Federal Regulations

Federal Regulations require state DOTs and MPOs to consider and include bicycle and pedestrian transportation facilities in their engineering and planning activities:

- ***Title 23 U.S.C 217 Bicycle Transportation and Pedestrian Walkways***

  (e) Bridges. In any case where a highway bridge deck being replaced or rehabilitated with Federal financial participation is located on a highway on which bicycles are permitted to operate at each end of such bridge, and the Secretary determines that the safe accommodation of bicycles can be provided at reasonable cost as part of such replacement or rehabilitation, then such bridge shall be so replaced or rehabilitated as to provide such safe accommodations.

  (g) Planning and Design.

  (1) In general - Bicyclists and pedestrians shall be given due consideration in the comprehensive transportation plans developed by each metropolitan planning organization and State in accordance with sections 134 and 135, respectively. Bicycle transportation facilities and pedestrian walkways shall be considered, where appropriate, in conjunction with all new construction and reconstruction of transportation facilities, except where Active Transportation users are not permitted.

(2) Safety considerations - Transportation plans and projects shall provide due consideration for safety and contiguous routes for bicyclists and pedestrians. Safety considerations shall include the installation, where appropriate, and maintenance of audible traffic signals and audible signs at street crossings.

- ***Title 23 U.S.C. 109 Standards***

  (m) Protection of non-motorized transportation traffic. The Secretary shall not approve any project or take any regulatory action under this title that will result in the severance of an existing major route or have significant adverse impact on the safety for non-motorized transportation traffic and light motorcycles, unless such project or regulatory action provides for a reasonable alternate route or such a route exists.

2.2.2. Required Accessible Facilities

ODOT has adopted the *Draft 2011 PROWAG* as the governing document for accessible design within ODOT's public right-of-way. The implementation of accessible designs depends on project type:

- **New construction** – New construction projects are defined as projects where roadway facilities do not currently exist. All new construction projects with pedestrian facilities shall incorporate accessible design elements conforming to PROWAG and ODOT design requirements.
- **Alteration projects** – Alteration project, also called Reconstruction Projects, include projects that reconstruct or rehabilitate any portion of an existing facility located within the highway right-of-way. These projects can include full depth replacement, alteration of design elements, lane width, shoulder width or adding lanes. Existing pedestrian facilities on these roadways that are impacted by the project require reconstruction to meet current ADA requirements. Pedestrian facilities that are not disturbed but are within the project limits shall be evaluated for ADA compliance. If found non-compliant, the facility may require replacement within the project limits based on the scope of the project. Alteration projects may also include the construction of new accessible facilities, such as new curb ramps or pushbuttons, to improve accessibility at an intersection.
- **Unaltered Facilities** - For unaltered, existing facilities, no changes to existing accessible facilities is required, nor are new accessible facilities required, unless an alternation project is identified for the facility. At that time, any non-compliant facilities within the project corridor must be made compliant as directed under the Alteration Projects section of this guide.

2.2.2.1 ADA Compliance Evaluation for Alteration Projects

Resurfacing is an alteration that triggers the requirement to add curb ramps if it involves work on a street or roadway spanning from one intersection to another and includes overlays of additional material to the road surface, with or without milling. Examples include, but are not limited to, the following treatments or their equivalents: addition of a new layer of asphalt, reconstruction, concrete pavement rehabilitation and reconstruction, open-graded surface course, micro-surfacing and thin lift overlays, cape seals and in-place asphalt recycling.

Projects classified as maintenance do not trigger an evaluation of existing curb ramps and the addition of new curb ramps. Maintenance treatments are those that serve solely to seal and protect the road surface, improve friction, and control splash and spray because they do not significantly affect the public's access to or usability of the road. Some examples of the types of treatments that would normally be considered maintenance are: painting or striping lanes, crack filling and sealing,

surface sealing, chip seals, slurry seals, fog seals, scrub sealing, joint crack seals, joint repairs, dowel bar retrofit, spot high-friction treatments, diamond grinding, and pavement patching.

A curb ramp evaluation form is available online in ODOT's ADA Design Resource.

2.2.3. Statewide Bicycle and Pedestrian Goals

ODOT's Statewide Bicycle and Pedestrian Plan, Walk.Bike.Ohio (WBO), sets forth a vision and key goals to guide Ohio's investments in multimodal infrastructure and programs. As a modal plan focused on bicyclists and pedestrians, this plan also informs ODOT's overarching Long Range Transportation Plan: Access Ohio 2045 as well as the Strategic Highway Safety Plan. WBO documents multiple benefits to the State of Ohio from multimodal transportation facilities, including emissions reductions, cost savings, and community health improvements. The inclusion or improvement of multimodal facilities is necessary to allow roadway users to safely and freely move using active transportation, primarily walking and bicycling, across rural, suburban, and urban settings.

Effective active transportation networks often lead to more people walking, bicycling, and riding transit by creating routes that are efficient, seamless, and easy to use. All projects, alternatives analyses, and processes impacting bicycle and pedestrian transportation should be developed in alignment with the vision and goals of WBO. Projects should also be developed according to their Purpose and Need.

Vision: Walking and bicycling in Ohio will be a safe, convenient, and accessible transportation option for everyone.

Goals:

- Equity: Ensure the system accommodates users of all ages, abilities, and incomes. Provide opportunities for all Ohioans in urban, suburban, and rural areas to have access to connected walkways and bikeways.
- Network Utilization: Increase walking and bicycling usage. Work to increase active transportation for all ages and abilities.
- Network Connectivity: Promote comfortable and continuous bicycle and pedestrian facilities that connect people to destinations. Expand the active transportation network to include connected, separated and accessible walkways and bikeways.
- Safety: Reduce bicyclist and pedestrian injuries and fatalities. Work actively and collaboratively with federal, state, regional, local, and private partners to make Ohio safer for people who walk and bike.
- Livability: Improve the quality of life for all Ohioans. Provide active living environments with safe, connected, accessible facilities along with programs that influence public health and the environment by encouraging walking and bicycling.
- Preservation: Ensure critical existing infrastructure is in a state of good repair. Maintain existing active transportation facilities through collaboration between state and local partners to ensure safe, accessible walkways and bikeways.

When planning, programing, scoping, and designing walking and bicycling facilities, designers should be guided by WBO's vision and goals.

2.3 Project Life Cycle

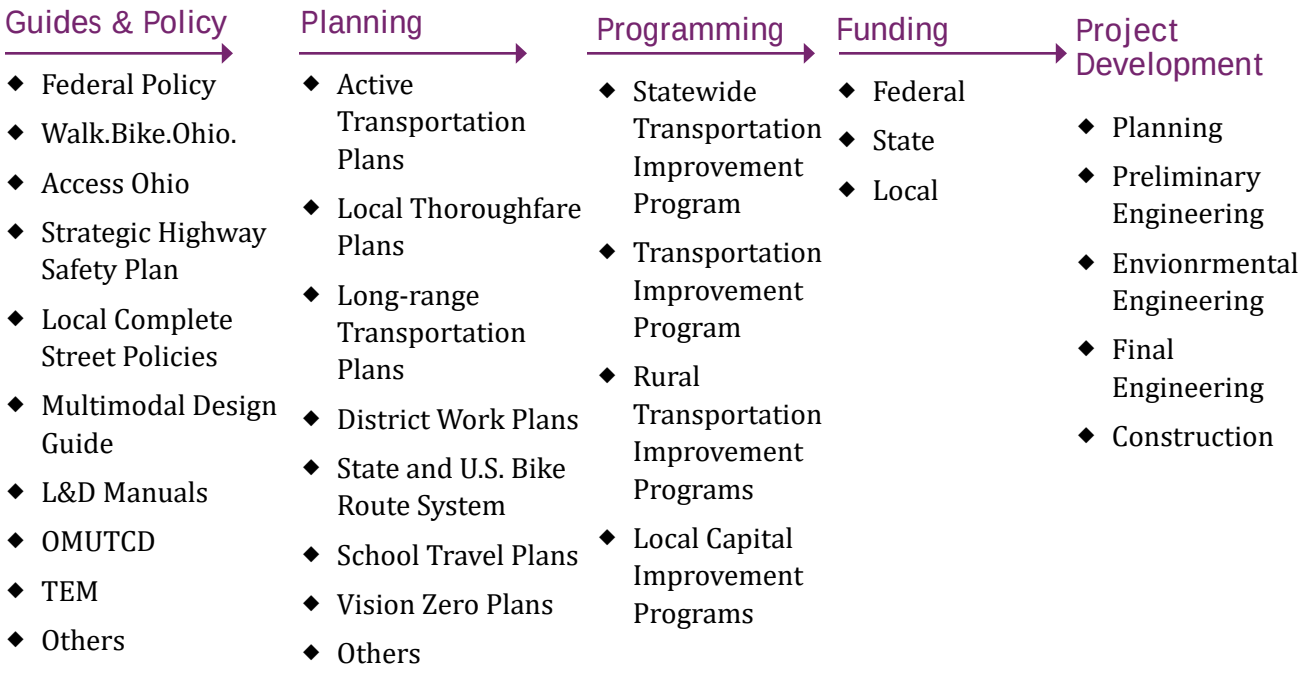
2.3.1. Planning

Figure 2-1 generally describes the process of moving any project type from planning and programing to construction.

Bicycle and pedestrian accommodations may be identified and documented within a variety of planning documents or policies. This may include Long Range Transportation Plans, local thoroughfare plans, complete streets policies, active transportation plans, school travel plans, etc. For guidance on developing active transportation plans, which specifically document the needs of pedestrians and bicyclists, see ODOT's Active Transportation Plan Development Guide.

Where plans are unavailable, or do not consider the needs of pedestrians or bicyclists, Chapter 2 can be used to determine if and what type of pedestrian and bicycle facilities should be provided in a project during the planning stage. By considering the potential need for pedestrian and bicycle facilities early in the process, projects can be programed and funded appropriately. Where Complete Street Policies have been adopted, planners and designers must also follow guidance laid out in the Policy.

Figure 2-1: Project Life Cycle



2.3.1.1 Planning Resources

ODOT maintains a variety of transportation system information that project managers can leverage to inform their decision making during the planning and programing process. The following tools provide some important information on existing conditions and can contribute to a prudent and context-sensitive approach to individual projects.

Table 2-1: Planning Resources

Resource	Description
Active Transportation Demand and Need Analysis	During WBO's planning process statewide active transportation demand and needs analyses were conducted. The results of the analysis can be viewed in TIMS and provide a general understanding of if there is a high demand or high need in the project area. For more information see Walk.Bike.Ohio's Needs Analysis Report and Walk.Bike.Ohio's Demand Analysis Report.
Transportation Information Mapping System (TIMS)	ODOT's web-mapping portal contains many comprehensive datasets that are relevant to multimodal transportation projects. These include: • ADA Pushbutton Inventory • ADA Crosswalk Inventory • ADA Curb Ramp Inventory • ADA Sidewalk Inventory • ADA Refuge Island Inventory • State and US Bike Routes • Road Inventory and Traffic Counts TIMS is a good starting point for project managers to familiarize themselves with existing conditions. It can help identify potential multimodal transportation challenges and opportunities, which should be verified through field work or local expertise. In addition, the Active Transportation Map Viewer provides an online interface to view layers related to active transportation planning, including previously planned bicycle and pedestrian projects.
Non-Motorized Database System	The Non-Motorized Database System (NMDS) is a powerful tool for the traffic engineer or planner to organize the agency's non-motorized count data. It provides a dashboard level summary of the system as well as tools to maintain, review, and report data at the path level. From bike lanes to sidewalks to bike paths to trails, the NMDS module helps manage the data.
GIS Crash Analysis Tool	GCAT uses GIS (Geographic Information Systems) to produce data that is spatially located to provide a convenient safety crash analysis tool. It allows users to filter data by type of unit (e.g., bicyclist or pedestrian), crash type and severity, contributing circumstances, and other attributes. GCAT helps project managers identify trends in pedestrian and bicycle crashes within their study area, which in turn can guide countermeasure selection to improve safety.
Economic Crash Analysis Tool (ECAT)	The ECAT has the ability to calculate predicted crash frequencies, complete empirical bayes calculations, predict crash frequencies for proposed conditions, conduct alternatives analyses, and complete a benefit-cost analysis.
StreetLight Data	StreetLight Data is an analytics company that organizes and interprets anonymous location data to provide meaningful travel metrics with high spatial accuracy. StreetLight data for Ohio is accessible to any public agency or University within Ohio. It can also be made temporarily available to any consultant working on a public agency's projects; consultant access is limited to use on those public agency projects. To access the account, contact the Office of Roadway Engineering. To ensure the most accurate information possible for bicycle and pedestrian volumes, ODOT uses permanent and short-duration counts to validate and calibrate StreetLight and other third-party data sources. More information can be found in the Ohio Nonmotorized Monitoring Program Implementation Plan.
Walk.Bike. Ohio	WBO is ODOT's first plan to focus on walking and bicycling policies and programs around the state.The plan guides Ohio's bike and pedestrian transportation policies and investments in infrastructure and programs. As part of this, an analysis of bicycle and pedestrian safety data from 2009 to 2018 is available for download through their website. Additionally, a User Types and Facilities report was also published and covers the impact of land use and network connectivity on the user experience at a high level.

2.3.2. Programing and Funding

ODOT is required by federal law to develop a Statewide Transportation Improvement Plan (STIP) that facilitates the safe and efficient management, operation, and development of surface transportation systems that will serve the mobility needs of people and freight and includes accessible pedestrian walkways and bicycle transportation facilities. The STIP is developed in cooperation with Ohio's Metropolitan Planning Organizations (MPOs) and in consultation with non-metropolitan local officials, Indian Tribal governments, the Secretary of the Interior, State, Tribal, and local agencies responsible for land use management, natural resources, environmental protection, conservation, and historic preservation. Collaboration and consultation with these stakeholders will ensure prioritization of projects is consistent with the goals and objectives identified by the State, MPOs and locals.

It is the responsibility of each project sponsor to review state and local transportation plans, to ensure an appropriate level of accommodation for pedestrians and bicyclists is constructed on the specific project they are programming, developing and/or managing. Where local plans do not exist, or do not consider all modes, the following may be used to determine the appropriate level of accommodations for pedestrians and bicyclists:

- Context sensitive guidance for the provision of pedestrian and bicycling facilities (see Sections 2.4 and 2.5);
- Public engagement (see Section 2.6); and
- Multimodal analysis tools as appropriate (see Section 2.7).

Selecting pedestrian and bicycling accommodations should be guided by Ohio's Statewide Bicycle and Pedestrian Plan goals (see Section 2.2.3) and each project sponsor should coordinate this process with their ODOT District Bicycle and Pedestrian coordinator and MPO. Early identification and engagement with stakeholders during the public engagement process is strongly encouraged.

There are many simple and cost-effective ways to integrate or improve non-motorized users into the design and operation of Ohio's transportation system, by including pedestrian and bicycle accommodation as a part of larger ongoing projects. Examples include:

- Providing paved shoulders on new and reconstructed roads.
- Restriping roads (either as a stand-alone project, or after a resurfacing or reconstruction project) to create a striped bike lanes.
- Building sidewalks and shared use paths, installing traffic calming, and marking crosswalks or on-street bike lanes as a part of new highways or roadways.
- Requiring new transit vehicles to have bicycle racks and/or hooks installed and providing pedestrian and bike facility connections within a reasonable radius of bus stops (see Section 2.5.3).

Federal surface transportation law provides flexibility to states and MPOs to fund bicycle and pedestrian improvements from a wide variety of programs. Virtually all the major transportation funding programs can be used for bicycle and pedestrian-related projects. When considering

ways to improve conditions for bicycling and walking, MPOs and local governments should review and use the most appropriate funding source for a particular project and not rely primarily on Transportation Alternatives Program funding. Many bicycle and pedestrian projects can be eligible and meet the goals of other programs, such as the Congestion Mitigation and Air Quality Improvement Program, the Surface Transportation Program, the Highway Safety Improvement Program, the Safe Routes to School Program, the Clean Ohio Trails Fund, the State and Local Capital Improvements Program, the Recreational Trails Program, Community Development Block Grants, and the Federal Transit, Capital, Urban & Rural Program.

Most funding programs require a local dollar match, and the amount will differ depending on the program. It is usually encouraged to provide above the minimum required amount and pair other funding sources for a local government to be competitive. Funding programs are administered by several agencies including the Ohio Department of Transportation, Ohio Department of Natural Resources, Ohio Public Works Commission, Ohio Department of Development, MPOs, regional transit authorities, and Housing and Urban Development entitlement Cities & Counties.

2.3.3. Project Development Process

Once a project has been funded, the Project Development Process (PDP) may begin. In the first phase of the PDP process, Chapter 2 can be used in conjunction with the PIP and public engagement to assess if there are additional pedestrian and bicycle facility needs within the project area. If a need is identified, it should be documented through the project Purpose and Need Statement. Project managers may need to reevaluate funding needs depending on the findings of this process.

Subsequent sections provide additional guidelines for specific stages of the PDP. For a complete overview for all project types, see the **PDP Manual**.

2.3.3.1 Purpose and Need Statement

A project's Purpose and Need Statement guides the project from development through construction. A well-defined and well-justified Purpose and Need Statement should clearly define the primary and secondary transportation needs that show that a No Build alternative will not solve an existing transportation problem. A good Purpose and Need Statement helps to both develop the project scope and aid in the selection of a preferred alternative for the project. The Purpose should clearly define the transportation problem to address the issue. The Need will provide data to support the problem statement (i.e., Purpose), which could include issues of safety, existing deficiencies, user demand, equity, etc.

Section 2.2.3 summarizes ODOT's statewide vision and goals for walking and biking in the state and may be used as a guide at this stage. Statewide active transportation demand and needs analyses can be viewed in TIMS and provide a general understanding of if there is a high demand or high needs for active transportation in the project area, see Table 2-1. The findings of this high demand and high need analysis may be used to support a project's Purpose and Need Statement.

Stakeholder involvement is also an essential element for establishing the project's Purpose and Need Statement. See Section 2.6 for more information on stakeholder and public engagement.

For general information regarding developing a Purpose and Need Statement, see ODOT's **Developing Purpose and Need Guidance**.

2.3.3.2 Preliminary Engineering

In addition to the feasibility study and preliminary engineering activities laid out in the Preliminary Engineering Phase of the PDP, the following should be considered for project scopes that include pedestrian and bicycle facilities:

- Include multimodal level of service and bicycle and pedestrian performance metrics as typical criteria for feasibility studies and alternatives analysis. This could include:
  - » Pedestrian and bicyclist count data as part of traffic data
  - » Pedestrian and bicyclist crash data as part of the safety analysis
  - » Pedestrian and bicyclist delay under existing and future conditions
- Consider conducting road safety audits, walkability audits, and bikeability audits to gather information on existing conditions that may be applicable to safety.
- Where accommodations for pedestrians and/or bicycles are identified in the project purpose, approaches to cross-section formulation should be presented from right-of-way edge to edge rather than from the centerline out to ensure that accommodation of all modes is positively encouraged in the preliminary design development.
- For larger, complex projects, the Highway Capacity Manual: A Guide for Multimodal Mobility Analysis (HCM2016) should be used in an effort to quantitatively assess and balance the level and quality of performance for each mode. This analysis could result in independent levels of service for pedestrians, bicyclists, transit users, and motor vehicle drivers, with a solution that is designed to provide equivalent levels of safety and services for each mode. Another approach is to emphasize safety by prioritizing the needs of the most vulnerable users of the street. The safety of pedestrians, as the most vulnerable street users, would receive priority in this case.
- For interchange projects, pedestrian and bicyclist needs should meet the best practices laid out in Chapter 9: Multimodal Accommodations at Interchanges & Alternative Intersections.

2.4 Context-Sensitive Design

Context-sensitive design asks questions first about the need and purpose of the transportation project, and then equally addresses safety, mobility, and the preservation of scenic, aesthetic, historic, environmental, and other community values. It results in projects that are sensitive to, and incorporate, local circumstances and priorities, and can generate greater community support.

This guide distinguishes five land use context classifications for the purposes of planning and designing for people walking and bicycling. The five context classifications are shown in Figure 2-2 and are generally defined by development density (existence of structures and structure types),

land uses (primarily residential, commercial, and/or agricultural), and building setbacks (distance of structures to adjacent roadways). While a street may have one functional classification, it may pass through multiple context classifications, and the transitions between those classifications is often gradual. Possible changes in context classification resulting from future development must also be considered in design. Understanding the context classification is important to conduct a more thorough assessment of multimodal needs to identify priorities among transportation modes within a corridor.

Figure 2-2: Land Use Types (Source: Florida DOT Context Classifications Modified by Toole Design)

LAND USE CONTEXT CLASSIFCATION	RURAL		RURAL TOWN	SUBURBAN		URBAN		URBAN CORE
LAND USE TYPE	*NATURAL*	*AGRICULTURAL*	*RESIDENTIAL OR COMMERCIAL*	*RESIDENTIAL*	*COMMERCIAL*	*RESIDENTIAL*	*COMMERCIAL*	

2.5 Pedestrian and Bicycle Accommodations

The following sections discuss when to and what type of pedestrian or bicycle facility to consider based on context. Existing data and analyses listed in Sections 2.3.1 and 2.7 are available to support the planning process. Designers should use this section in conjunction with public engagement to determine a project's scope of work.

2.5.1. Pedestrian Facilities

The provision of facilities to accommodate pedestrians along and crossing roads is essential for the safe movement of people walking. Other than on limited access freeways where pedestrians are prohibited, the provision of pedestrian facilities should be assessed along any road where pedestrians are permitted, including along rural and suburban highways. In rural town, suburban, and urban land uses, pedestrians are expected and a well-connected pedestrian network is necessary to provide for safe travel.

In addition to the required provisions stated in Section 2.2.1 and 2.2.2, pedestrian accommodations should be provided where the following conditions are present:

- In residential and commercial urban core, urban, suburban, and rural town context classifications
- Along corridors with pedestrian travel generators and destinations (i.e., schools including colleges and universities, public parks, commercial centers, community centers including public libraries, government buildings, hospitals, transit stops, etc.), or areas where such generators and destinations can be expected prior to the design year of the project
- Where there is an occurrence of reported pedestrian crashes that could be mitigated by providing separate sidewalk/walkways
- Where there is evidence of pedestrian traffic (e.g., counts, a worn path along a roadway, etc.)
- Where a need is identified by a local government or MPO through an adopted planning study or where existing or future land uses indicate a need
- Where the project area has a high Active Transportation Need and Demand score
- On all new and widened bridges where any of the criteria listed above are met

2.5.1.1 Sidewalk and Walkway Facility Selection

Table 2-2 provides recommendations for sidewalk and walkway types for various land use context classifications. Sidewalks should also be considered on all projects which provide curb-and-gutter and in areas where there is obvious pedestrian use (such as worn footpaths). A sidewalk or walkway should be provided on both sides of the roadway.

Table 2-2: Guidelines for New Sidewalk/Walkway Installations

Land Use Context Classifications	Sidewalk/Walkway
Rural	Paved shoulders
	Shared Streets
	Shared use paths
Suburban	Sidewalks on both sides of the roadway
	Shared use paths
Urban Core, Urban, and Rural Town	Sidewalks on both sides of the roadway
	Shared Streets
	Shared Use Path

2.5.1.2 Pedestrian Crossings

Whether marked or unmarked, crosswalks exist at all legs of all intersections represented by the extension of the property lines, curb lines, or edge of the traversable roadway through the intersection, including T-intersections, except where signs prohibit pedestrian crossings. However, as intersecting traffic volumes approach 9,000 vehicles/day, vehicle speeds exceed 30 mph, or the number of travel lanes to be crossed exceed two lanes, the rate of motorist yielding on the uncontrolled approach drops significantly which can create crossing challenges for people walking or bicycling. In these instances, designers should consider enhanced crossings treatments at currently uncontrolled intersections or mid-block where signalized crossings exceed 600 ft.

Crossings should be located where there is a desire to cross due to existing or future land use. Examples of this include:

- Schools, public parks, libraries, or community centers located across a street
- Commercial centers, public parks, government centers, and hospital or school/university campus spanning across a street
- Transit stops
- Existing pedestrian demand demonstrates a need (e.g., counts, parking lot and office building on opposite sides of the roadway, shared use path crossings, etc.)

When evaluating a corridor to determine appropriate enhanced crossings, it is important that designers consider both land uses and destinations along the corridor as well as in the areas immediately adjacent to the corridor. For example, a commercial street may be surrounded by residential areas that contain parks and schools. Considering pedestrian circulation to those major destinations within neighborhoods will help designers identify key crossings along the commercial corridor that serve the larger area as well as land uses along the street.

Pedestrian and bicycling crashes should also be reviewed to determine if an enhanced crossing should be provided at an uncontrolled intersection or mid-block location. However, a lack of crashes does not always indicate that existing crossings are safe (see Section 2.7.2).

To promote and achieve high compliance, mid-block crossings should be located where intersection spacing is greater than 600 ft, and there is a natural desire line for the pedestrian's path of travel (as described above). Mid-block crosswalks should typically not be installed within the functional area of intersections. They should be located a minimum of:

- 200 ft. from signalized intersections
- 120 ft. to 200 ft. or more from unsignalized intersections.[1]

Selecting pedestrian crossing treatments and designing for safe crossings is discussed in Sections 4.4 and 4.5. For crossing design of uncontrolled intersections along bicycle boulevards, see Section 6.3.2 and 6.5.6.

2.5.2. Bicycle Facilities

Bicyclists should be expected on all roadways except where prohibited by law. A network of safe, comfortable, connected, and intuitive bikeways supports bicycling as a viable, convenient, and appealing mode of transportation for people of all ages and abilities. Communities with a well-designed and maintained bicycle network typically have higher rates of bicycling. A safe and connected network provides users with a comfortable place to ride over the course of their entire trip. In urban and suburban centers and rural towns, where a large share of trips are shorter than three miles in length, there is opportunity for bicycling as a transportation mode to complement recreational bicycle activity. A bikeway should typically be provided when any of the following conditions are met:

- If the project is on a U.S., state, regional, or local bicycle route
- Where a project connects to an existing bikeway (e.g., bicycle boulevard, paved shoulder, bicycle lane, separated bicycle lane, or shared use path)

- Along project alignments or within close proximity to bicycle travel generators and destinations (i.e., residential neighborhoods, commercial centers, schools, colleges, scenic byways, public parks, transit stops/stations, etc.)
- Within a 3-mile bicyclist catchment area of an existing fixed-route transit facility (i.e., stop, station, or park-and-ride lot). A catchment area is defined by a radial distance from a transit facility per Federal Transit Administration (FTA) guidelines - this includes crossing and intersecting streets
- Where there is an occurrence of reported bicycle crashes that could be mitigated through the provision of a bikeway
- Where the project area has a high Active Transportation Need and Demand score
- On all new and widened bridges when any of the criteria listed above are met

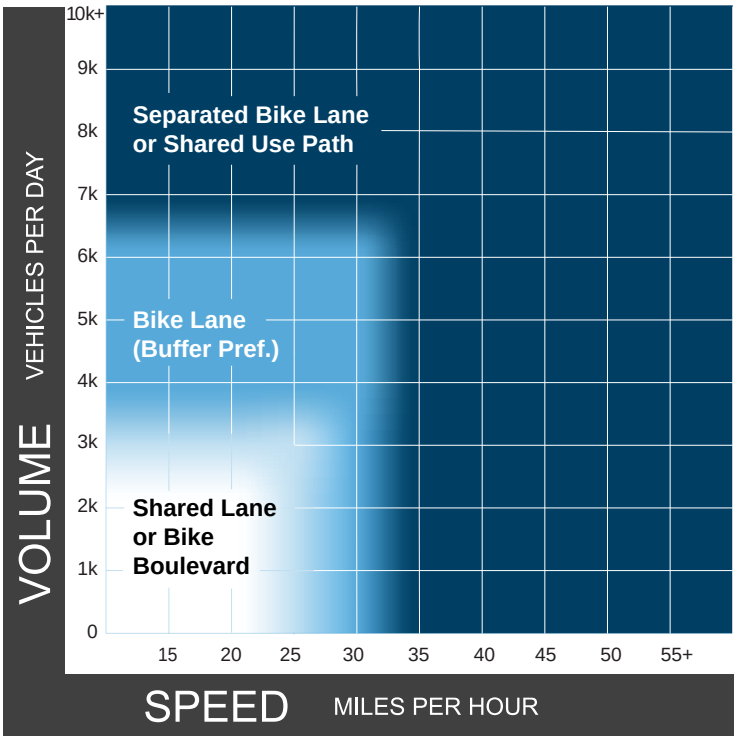
2.5.2.1 Bikeway Facility Selection

The selection of a preferred bikeway requires a balance of data analysis and engineering judgment working within relevant constraints for the project. Key criteria includes the target design users, traffic conditions, and land use contexts. Before beginning this process, designers should be familiar with the different bicycle design user profiles discussed in Section 3.2.1.

Proximity to motor vehicle traffic is a significant source of stress and discomfort for bicyclists. Crash and fatality risks sharply rise for vulnerable users when motor vehicle speeds exceed 25 mph. Further, as motorized traffic volumes increase above 6,000 vehicles/day, it becomes increasingly difficult for motorists and bicyclists to share roadway space. For example, on a roadway with 10,000 vehicles/day, a bicyclist traveling at 10 mph will be passed approximately every four seconds by a motor vehicle during the peak hour.

Figure 2-3 provides guidance for how motor vehicle volume and speed should be taken into consideration to determine a preferred bikeway type in the rural town core (e.g., main streets), suburban, and urban contexts for the Interested but Concerned Bicyclist. The preferred bikeway type shown in Figure 2-3 is based on

Figure 2-3: Preferred Bikeway Type for Interested but Concerned Bicyclists in Urban Core, Urban, Suburban and Rural Town Contexts



Notes

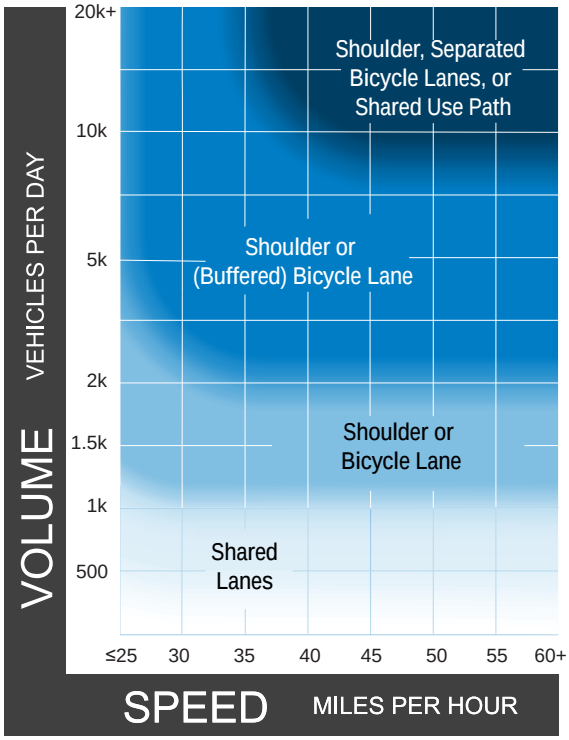
1 *Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.*

2 *See Section 2.8.1 for a discussion of alternatives if the preferred bikeway type is not feasible.*

Bicyle Level of Traffic Stress (LTS). If the roadway in question cannot physically accommodate the preferred bikeway type, refer to Section 2.5.2.2.

Rural roadways, shared lanes, bike lanes, paved shoulders, and shared use paths are potential bikeway types. Highly Confident or Somewhat Confident Bicyclists are most likely to travel long distances on rural roadways between towns and cities and are therefore often assumed as the default design user profiles. Figure 2-4 shows when a shoulder (or other bikeway) should be provided to accommodate these bicyclists based on traffic volumes and posted speeds in the rural context. The preferred bikeway type shown in Figure 2-4 is based on the Bicycle Level of Service (LOS) as described in the Highway Capacity Manual. Designing for the Highly Confident or Somewhat Confident Bicyclists will not accommodate people of all ages and abilities. For agencies that have identified that there is a need for an all ages and abilities facility, Figure 2-3 should be used for the Interested but Concerned design user profile.

Figure 2-4: Preferred Bikeway for Highly Confident Bicyclists in Rural Contexts



Notes

1 *Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.*

2 *If the percentage of heavy vehicles is greater than 10%, consider providing a wider shoulder or a separated pathway.*

Along rural roads with higher speeds (45 mph or greater) it is preferable to provide a shared use path separated from the road if the road segment:

- is a well-used and important bicycle route
- is located in an area that attracts larger volumes of bicycling due to scenic views
- serves as a key bicycle connection between major destinations
- serves a population of bicyclists who fit the Interested but Concerned Bicyclist Profile

2.5.2.2 Bikeway Feasibility Assessment

Once the preferred bikeway type is identified, designers will need to assess its feasibility in the given project location against potential project constraints which could limit the ability to implement the preferred bikeway. This assessment may involve determining whether additional separation between motorists and bicyclists is warranted, identifying portions of the roadway to reallocate to achieve desired widths, selecting the "next best" bikeway, or selecting an alternative route for the bikeway.

Designers have an obligation to provide for the health, safety, and welfare of the public, which may require a careful evaluation of mobility and safety for each user. When evaluating safety trade-

offs, options that reduce serious injuries and fatalities should be prioritized over options that may reduce property damage or minor injuries.

Conditions for Increasing Separation

There are a variety of conditions that may indicate the need for greater separation between motorists and bicyclists, which could increase the width of the bikeway or materials used in the buffer. The conditions where greater separation may be appropriate to accommodate the selected design user include:

- Unusual peak hour motor vehicle volumes (more than 8 to 12 percent of AADT),
- High percentage of heavy vehicles (trucks, buses, and heavy vehicles are more than 5 percent of traffic),
- Motor vehicle operating speeds exceed posted speed
- Frequent parking turnover or heavy curbside activity,
- High volumes of bicyclists (500 bicyclists per hour),
- Presence of vulnerable populations (i.e., school children),
- Network connectivity gaps,
- Proximity to transit; and
- Frequent driveways.

Options for Reallocating Roadway Space

When constructing new roads, bikeways should be built to the recommended minimum dimensions rather than constrained dimensions. For retrofit projects, it may be necessary to evaluate options that reallocate existing space or use minimum or constrained dimensions. The following are strategies for reallocating roadway space to accommodate a bikeway:

- Narrowing wider than necessary travel lanes, including medians/turn lanes;
- Removing travel or turn lanes;
- Removing parking on one side of street; and
- Converting angled parking to parallel parking.

Designers should refer to Section 7.5 reallocating street space for additional guidance.

Selecting the "Next Best" Bikeway Type or Parallel Routes

Impacts on ridership, comfort/stress, safety, and overall network connectivity should be considered when evaluating alternative bikeway designs or potential parallel routes to ensure the project will still meet the purpose identified at the outset. The following trade-offs should be considered and documented in the design process:

- Reduced or suppressed ridership where the bikeway does not meet the needs of the target design user;

- Additional length of trip when bicyclists must use a parallel route. This length should not exceed 30 percent more than original route and should not add excessive delay;
- Critical gaps in the network when projects fail to provide bicycle accommodations;
- Reduced safety where bicyclists must operate with relatively high motor vehicle speed and/or high-volume traffic in shared lanes;
- Reduced safety where bicyclists must operate in narrow space (e.g., narrow bike lanes adjacent to parking lanes or narrow shared use paths with high volumes of pedestrians or bicyclists)
- Reduced safety where bicyclists improperly use facilities (e.g., bicycle the wrong way on shared lanes, sidewalk riding, etc.); and
- Increased sidewalk bicycling where bicyclists are avoiding low-comfort/high-stress roadway conditions.

If selecting a parallel route as the preferred route for the Interested but Concerned Bicyclist occurs, the provision of a bikeway along the desired route should still be considered to accommodate the Highly Confident design user and to provide connections for bicyclists to and from properties that exist along that desired route. An example would be the provision of a bike lane or shoulder on a higher volume roadway which can benefit the Highly Confident bicyclists while a convenient, direct parallel route on an adjacent low volume street serves the Interested but Concerned Bicyclists.

2.5.3. Transit

Transit cannot function without people getting to and from the transit stop or station. This access must be safe, comfortable, and convenient to allow transit to serve as a high-quality transportation option and system.

Bicycle transportation is particularly effective in combination with transit systems: when used together, each expands the range of the other mode. Linking bicycles with transit can help people overcome such barriers as lengthy trips, trips where transit service exists on some but not all of the route, long transfer times between transit routes, personal security concerns, poor weather, and riding at night or up hills. Connecting transit stops and stations with a network of bicycle facilities is an important element of planning for bike-to-transit trips.[2]

The Federal Transit Administration considers bike facilities within three (3) miles of a public transportation stop eligible for funding due to their "*de facto* functional relationship."[3] Routes designed to help people access public transportation stops are commonly referred to as "first- and last-mile connections."[4]

Planning for first- and last-mile connections should consider:[5]

- Low-stress bicycle routes to arrive at transit stations and stops.
- Seamless connections to long-term, short-term, and sheltered bike parking that does not require dismounting.
- Bicycle storage on transit vehicles, such as "bikes-on-buses" and "roll-on rail" access.
- Adequate parking.

Providing safe and accessible pedestrian facilities at transit stops is important to facilitate mobility. Similar to bicycle first- and last-mile needs, connectivity to the sidewalk network and accessibility to other mobility options such as bicycles, scooters, or park and ride lots provide pedestrians options to travel beyond the stop to their destinations. While individual transit agencies within Ohio have specific design criteria, coordinating stop locations, crosswalks, and crossing frequency, and identifying additional crossing treatments such as high visibility crosswalk markings, crossing islands, flashing crossing signs, rapid rectangular flashing beacons, or pedestrian hybrid beacons on corridors will be helpful to address pedestrian comfort and safety.

2.5.4. Facilities that Prohibit Multimodal Users

Some roadways prohibit people walking and bicycling, such as highways and freeways. In these scenarios, facilities that prohibit walking and bicycling can create a barrier to pedestrian and bicyclist travel, particularly if the overall road network is sparse and alternative routes that would present minimal time or distance detour for pedestrians and bicyclist are not available.

When designing access-controlled roads—or projects in their vicinity—it is important for designers to review key origins and destinations and the alternate routes available to access them. Planners and designers should evaluate if ample crossings are provided so that people can cross the access-controlled road safely and legally, with minimal detour from a direct route between their origin and destination.

In some cases, the only roadway that connects a town to other destinations (e.g., employment or education centers) may be access-restricted to pedestrians and bicyclists, in which case it is particularly essential to consider the needs of multimodal users. In these cases, a shared use path should be considered to provide safe separation between high-speed vehicles, bicyclists, and pedestrians. Where there are no safe and legal routes for pedestrians or bicyclists immediately adjacent to or across an access-controlled corridor, designers should also consider providing a grade-separated facility to serve pedestrians and bicyclists to allow them to safely and legally cross the access-controlled corridor.

It is particularly important to provide safe and legal pedestrian and bicycle facilities when constructing bridges across a facility that prohibits these users, or across a similar barrier (such as a river), since crossing opportunities of such barriers for pedestrians and bicyclists are often not available where they may be needed or desired by these potential users.

2.6 Public Engagement

All of the tools described in this chapter contribute to the planning process. However, no tool is a substitute for public engagement. Involving the public in the planning and project development process is an essential tool in the planning and design of multimodal transportation facilities. It builds public trust in the process, improves the overall quality of work, ensures that the project aligns with local needs and priorities, and encourages community ownership of the final result.

People who walk and bike in the community have the best knowledge of current conditions as well

as specific opinions on areas that need new facilities or current facilities that may need design changes. Opinions and feedback of interested users who do not walk, bicycle, or use transit regularly (or at all) should also be sought to provide input regarding which facilities or programs would enable them to use multimodal transportation options. Designers should also consider hosting walk and bike audits with local stakeholders to better understand safety issues using both local knowledge and professional expertise.

For a project to serve a community, a diverse cross-section of people must guide the planning process. A blended approach that employs both traditional engagement strategies and more innovative methods is often the most effective way to gather a depth and diversity of perspectives that will ensure strong community support for the project. Conventional outreach efforts could include a website, community workshops and open houses, stakeholder meetings, and online surveys. These methods tend to not reach underrepresented communities as well as more innovative methods, such as focus groups, translated materials for non-English speakers, interactive, informative games, temporary demonstration projects, and pop-up tabling at community events. See the Active Transportation Plan Development Guide Chapter 3: Engage the Community for more information on community engagement including a list of engagement strategies with associated cost and reach of underrepresented communities.

The demographic characteristics of participants in public engagement events should reflect the demographics of the community being served, to ensure the full range of needs of the community are being met and that the planned outcomes reflect them. Project teams should make a concerted effort to engage marginalized and underserved groups, including communities of color, youth, older adults, individuals with low-income and/or low educational attainment, zero-vehicle households, people with disabilities, and limited English or non-English speakers. Earmarking budgets for these activities in advance is important to make sure the appropriate resources are available (e.g., interpreters).

A public engagement plan can help guide the engagement process and is required for certain projects under ODOT's NEPA public involvement requirements. Public engagement plans describe the approach and strategies for community and stakeholder outreach to build consensus throughout the planning and design process. They identify engagement tools and resources, target audiences, intended messages, and timing relative to milestones within the greater project schedule. Public engagement plans also include opportunities for stakeholders and elected officials to participate in community engagement and take ownership of the project. A public engagement plan is a living document that should be revisited and updated as needed throughout the project. The details of the engagement approach should be developed with significant input from key stakeholders and community groups, including advocates, elected officials, local transportation department staff, District staff, and Central Office staff.

More information on public involvement may be found on ODOT's website, ODOT's *Active Transportation Plan Development Guide,* its *Public Involvement Manual* for NEPA and the *Project Development Process*, and the regularly updated *Public Involvement Requirements document*.

2.7 Multimodal Analysis Tools

Below are several analyses that can be conducted for a single project. For information on network planning or planning for multiple project's see ODOT's Active Transportation Development Guide's Chapter 5: Assess Existing Conditions.

2.7.1. Safety Analysis

Analysis of crash trends and crash risk, particularly at intersections or along corridors where most crashes between active transportation users and motorists occur, is one of several factors that are helpful when selecting and designing appropriate pedestrian and bicycle facilities. By analyzing crash data, ideally in conjunction with volume data, planners and engineers seek to target specific areas, understand the combination of conditions that could be creating high crash rates, profile corridors with high crash risk, compare the characteristics of one facility type to another, and focus attention most effectively. When using crash data to determine potential locations for improvements to reduce the likelihood, frequency or severity of crashes, it is important to review at least three years of data to account for anomalies that might occur in a single year.

2.7.2. Perceived Safety Analysis

The perceived safety of walking or bicycling can be a barrier for a person to consider that mode of transportation. For pedestrians, perceived safety lies in personal safety and security. Sidewalk width and proximity to traffic lanes, especially high-speed traffic, can discourage pedestrian travel. Pedestrian crossings that are excessive in length, have confusing signal phasing or locations, or where pedestrian crossings intersect with fast turning vehicles impact perceived as well as actual safety. Factors such as pedestrian volumes and inadequate or no lighting is another perceived safety factor. Sidewalks with higher volumes of people walking tend to be viewed as more secure locations to walk. Dark or poorly lit sidewalks and sidewalks with few pedestrians may be viewed as unsafe, particularly for people walking alone.[6] Dark or poorly lit sidewalks also have direct impacts on actual safety; 75% of pedestrian deaths occur at night and can likely be attributed to inadequate lighting.[7]

Research has found a significant relationship between how safe and comfortable people feel bicycling, whether and how often they bicycle, their preferences for bicycle facility types, and the provision of those facilities.[8, 9, 10] If planners and designers know how safe people feel along various routes, they can plan and design for bicycling that overcomes those barriers.

Data on perceived safety provides important insights into street conditions and actual risks that crash data may not reflect. Various studies have found that pedestrian and bicycle crashes, even those involving motorists, tend to be underreported.[11, 12] A lack of crashes does not always indicate that there are no incidents, as studies have shown that near misses are more common than collisions and that these near-miss events impact a user's perception of their safety using the facility.[13, 14] Bicyclists who experience near-miss crashes are likely to be more vigilant. Still, they are also likely to be more concerned about bicycling conditions leading some people to avoid certain routes or stop bicycling.[15] Some streets which have few crashes are, in fact, streets which feel so

unpleasant or unsafe that very few people bicycle there. Thus, a small number of crashes does not necessarily indicate that a street is safe, but rather that there may be fewer people walking and bicycling or unreported crashes.

Walk and bike audits are often used to assess the safety and comfort of sidewalks, streets, and crossings within a community. Audits are conducted with residents of the study area or employees of local businesses interested in proving the walking and bicycling in their community. Though this process, designers can leverage local knowledge to better understand how people are using the network today and what deficiencies or safety issues are present that are not otherwise visible through available data and mapping.

2.7.3. Equity Analysis

Walking and bicycling is an important source of transportation for many at the lower end of the economic spectrum.[16] Planning processes can include a focus on making the multimodal transportation network accessible and safe for people of all socioeconomic and racial backgrounds, as well as people of any age and gender. During WBO's planning process statewide active transportation demand and needs analyses were conducted. The results of the analysis can be viewed in TIMS and provide a general understanding of if there is a high demand or high need in the project area. For more information on Equity analyses see Walk.Bike.Ohio's Needs Analysis Report and Walk.Bike.Ohio's Demand Analysis Report.

2.7.4. Cost-Benefit Analysis

Planning agencies can use cost-benefit analysis to quantify the impacts of bikeways and discuss them in easily understood terms. Costs are generally divided into one-time capital construction costs and ongoing annual operating costs. Application of a cost-benefit methodology to pedestrian and bicycle projects can allow comparison to motor vehicle and transit projects. A comparative cost-benefit analysis of planned bikeways can help prioritize projects that will have a high benefit-to-cost ratio. A cost-benefit analysis tool for bikeways can be found at the Pedestrian and Bicycle Information Center website.[17, 18] The benefit calculation includes estimates of mobility benefits (existing and new commuters), health benefits (estimated cost savings), recreation benefits (estimated value), and mode shift (reduced congestion, reduced air pollution, and user cost savings).[19]

2.7.5. Qualitative Indices

Some systems of evaluating bicycling and walking conditions are qualitative and based on surveys and observations. Examples include the Bicycle Environmental Quality Index from San Francisco and the City of Charlotte Level of Service Protocol.[20, 21] Walk audits are on-the-ground investigations that identify concerns related to pedestrian safety, access, comfort, and convenience. They allow transportation professionals to gain a local understanding of pedestrian challenges. In return, the public learns what kind of tools can be used to mitigate problems. Data and feedback gathered during the audit can inform policy and infrastructure recommendations. These and other qualitative approaches can be used to provide information for the planning and design process.

2.7.6. Pedestrian Demand Analysis

Understanding existing and potential levels of walking and bicycling is important in multimodal transportation planning, particularly if there is a need to prioritize among many potential capital investments. Estimating demand is less important when opportunities arise to incorporate the needs of pedestrians and bicyclists in roadway resurfacing and rehabilitation projects, since routine accommodations for walking and bicycling should be a standard operating procedure. Methods for determining pedestrian demand include Stated Preference and Corridor Level Analysis, described below.

2.7.6.1 Stated Preference

This method relies on public engagement to identify where people want to walk. It is a valuable and common tool used in many pedestrian planning efforts, but its effectiveness is limited to those populations who are able and willing to engage in the planning process. The needs of communities that have historically been ignored or marginalized in transportation planning, and who are often not included in transportation planning processes, (e.g., minorities; people with disabilities; people with lower income, financial resources, or who are experiencing homelessness; youth, people from a different national or cultural origin or who have limited English proficiency, etc.) are only captured in this process if equity is a deliberate focus of engagement activities.

2.7.6.2 Corridor Level Analysis

This method is used to estimate future pedestrian activity along a corridor if a certain facility type or improvement was provided, given a minimum level of pedestrian accommodation be achieved. Similar to sketch planning models, corridor level analysis requires robust contextual data, including existing number of utilitarian and recreational trips, proximity to populations and employment, level of service, and existing infrastructure quality.

2.7.7. Bicycle Demand Analysis

Evaluating bicycle travel demand shares some similarities to motor vehicle travel demand modeling. Both forecast future needs based on objective data inputs. Travel demand should consider latent demand (demand that is not apparent, but underlying) because existing conditions on a roadway are often a significant deterrent to bicycle travel, which can be alleviated through design changes. Therefore, bicycle travel demand methods make assumptions regarding how many people would choose to bicycle along a given corridor if conditions were conducive to bicycling based on surrounding land use information and other relevant variables.[22] Bicycle demand can also be established based on community priorities and goals. For example, if a mode shift goal is established for a community, then the analysis should assume that the mode shift goal will be achieved, and the appropriate mode shift percentages used for future analysis. Planning for the mode shift goal allows the goal to be achievable.

Planners and designers should also be aware that the peak hours for bicyclists may not correspond to the peak hours for motorists. For example, peak bicycle activity may occur during the mid-day on a weekend if the bike facility connects to a popular recreation destination. There may

also be significant land use-driven (e.g., university or school) or seasonal (e.g., summer vs. winter) variability in bicycling activity that should be considered when evaluating volume counts or projections.

Research shows that shorter distances between destinations and increased density and mixing of population, employment centers, schools, parks, transit stops, retail, and housing result in higher numbers of people bicycling for utilitarian, commuting, and recreational purposes, while longer distances between destinations and steep topography result in lower numbers of people bicycling.[23, 24, 25] Additional key factors are socioeconomic factors and the presence of safe bicycling infrastructure.[26] Network barriers, including crossings of freeways, interstates, railroads, or bodies of water, as well as roadways that are uncomfortable to bicycle on or cross, can substantially inhibit bicycling. Accordingly, these factors should be accounted for in estimates of anticipated bicycle travel demand with long-term planning working to address the network barriers.

Determinants of bicycling between rural and urban areas can be different, but the relative rates of bicycling are similar between the contexts based on analysis of the National Household Travel Survey data.[27] Rural areas may have reduced rates of utilitarian and commuting bicycling, but that can be offset by recreational bicycling trips.[28] In the U.S., older adults have been found to be more likely to bicycle in less urbanized areas than in highly urbanized areas.[29]

Chapter 2 Endnotes

1 NACTO Urban Street Design Guide

2 Schneider, R., Toole Design Group, College Park. *Transit Cooperative Research Program Synthesis 62: Integration of Bicycles and Transit*. TCRP, Transportation Research Board, Washington, DC, 2005.

3 76 F.R. 52046.

4 FTA. *Manual on Pedestrian and Bicycle Connections to Transit*. Report No. 0111, Federal Transit

5 Pucher, J. and R. Buehler, Integrating Bicycling and Public Transport in North America. *Journal of Public Transportation*, Vol. 12, No. 3, 2009, pp. 79-104.

6 *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. Washington, DC: American Association of State Highway and Transportation Officials. (2004, July).

7 National Center for Statistics and Analysis. (2019, March). *Pedestrians: 2017 data*. (Traffic Safety Facts. Report No. DOT HS 812 681). Washington, DC: National Highway Traffic Safety Administration.

8 Dill, D. and McNeil, N. Revisiting the Four Types of Cyclists. In *Transportation Research Record 2587*. TRB, National Research Council, Washington, DC, 2016.

9 Winters, M., G. Davidson, D. Kao, and K. Teschke. Motivators and Deterrents of Bicycling: Comparing Influences on Decisions to Ride. *Transportation*, Vol. 38, No. 1, 2010, pp. 153–168.

10 Sanders, R. L. We can all get along: The alignment of driver and bicyclist roadway design preferences in the San Francisco Bay Area. *Transportation Research Part A*, Vol. 91, 2016, pp. 120-133.

11 Lopez, D. S, D. B. Sunjaya, S. Chan, S. Dobbins, and R.A. Dicker. Using Trauma Center Data to Identify Missed Bicycle Injuries and Their Associated Costs. *Journal of Trauma and Acute Care Surgery*, Vol. 73, No. 6, 2012, pp. 1602-1606.

12 Stutts, J. C., and W.W. Hunter. *Injuries to Pedestrians and Bicyclists: An Analysis Based on Hospital Emergency Department Data*. FHWA-RD-99-078. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1997.

13 Sanders, R. L. Perceived Traffic Risk for Cyclists: The Impact of Near Miss and Collision Experiences. *Accident Analysis and Prevention*, Vol. 75, 2015, pp. 26-34.

14 Joshi, M.S., V. Senior, and G.P. Smith. A Diary Study of the Risk Perceptions of Road Users. *Health Risk Society*, Vol. 3, No. 3, 2001, pp. 261–279.

15 Aldred, R. (2016). Cycling near misses: Their frequency, impact, and prevention. *Transportation Research Part A: Policy and Practice, 90*, 69-83.

16 Turrell, G., M. Haynes, L.A. Wilson, and B. Giles-Corti. Can the Built Environment Reduce Health Inequalities? A Study of Neighborhood Socioeconomic Disadvantage and Walking for Transport. *Health and Place*, Vol. 19, 2013, pp. 89–98.

17 University of North Carolina Highway Safety Research Center. *Benefit-Cost Analysis of Bicycle Facilities*. [cited November 22, 2017]. Available from **http://www.pedbikeinfo.org/bikecost**.

18 Bushell, M. A., B. W. Poole, C. V. Zegeer, and D. A. Rodriguez. *Costs for Pedestrian and Bicyclist Infrastructure Improvements*. Prepared for the Federal Highway Administration by UNC Highway Safety Research Center, October 2013.

19 Krizek K., G. Barnes, G. Poindexter, P. Mogush, K. Thompson, D. Levinson, N. Tilahun, D. Loutzenheiser, D. Kidston, W. Hunter, D. Tharpe, Z. Gillenwater, and R. Killingsworth. *National Cooperative Highway Research Program Report 552: Guidelines for Analysis of Investments in Bicycle Facilities*. NCHRP, Transportation Research Board, Washington, DC, 2006.

20 Parks, J., A. Tanaka, P. Ryus, C. Monsere, N. McNeil, and M. Goodno. Assessment of Three Alternative Bicycle Infrastructure Quality-of-Service Metrics. In *Transportation Research Record 2387*. TRB, National Research Council, Washington, DC, 2014.

21 Brozen, M., T. Black, and R. Liggett. What's a Passing Grade? Comparing Measures and Variables in Multi-Modal Street Performance Calculations. In *Transportation Research Record 2420*. TRB, National Research Council, Washington, DC, 2014.

22 Aoun, A., J. Bjornstad, B. DuBose, M. Mitman, and M. Pelon. *Bicycle and Pedestrian Forecasting Tools: State of the Practice*. Prepared for the Federal Highway Administration, April 2015.

23 Schneider, R. J., H. Lingqian, and J. Stefanich. Development of a neighborhood commute mode share model using nationally-available data. *Transportation*, 2017, pp. 1-21.

24 Saelens, B. E., J.F. Sallis, and L. D. Frank. Environmental Correlates of Walking and Cycling: Findings from the Transportation, Urban Design, and Planning Literatures. *Annals of Behavioral Medicine*, Vol. 25, No. 2, 2003, pp. 80-91.

25 Griswold, J., A. Medury, and R. Schneider. Pilot Models for Estimating Bicycle Intersection Volumes. In *Transportation Research Record 2247*. TRB, National Research Council, Washington, DC, 2011.

26 Buehler, R., and J., Dill. Bikeway Networks: A Review of Effects on Cycling. *Transport Reviews*, Vol. 36, No. 1, 2016, pp. 9-27.

27 Rails-to-Trails Conservancy. *Active Transportation Beyond Urban Centers*. Rails-to-Trails Conservancy, Washington, DC, 2011.

28 Miranda-Moreno, L., T. Nosal, R. Schneider, and F. Proulx. Classification of bicycle traffic patterns in five North American Cities. In Transportation Research Record 2339, 2013, pp. 68-79.

29 Kemperman, A., and H. Timmerman. Influences of built environment on walking and cycling by latent segments of aging population. In *Transportation Research Record 2134*. TRB, National Research Council, Washington, DC, 2009.

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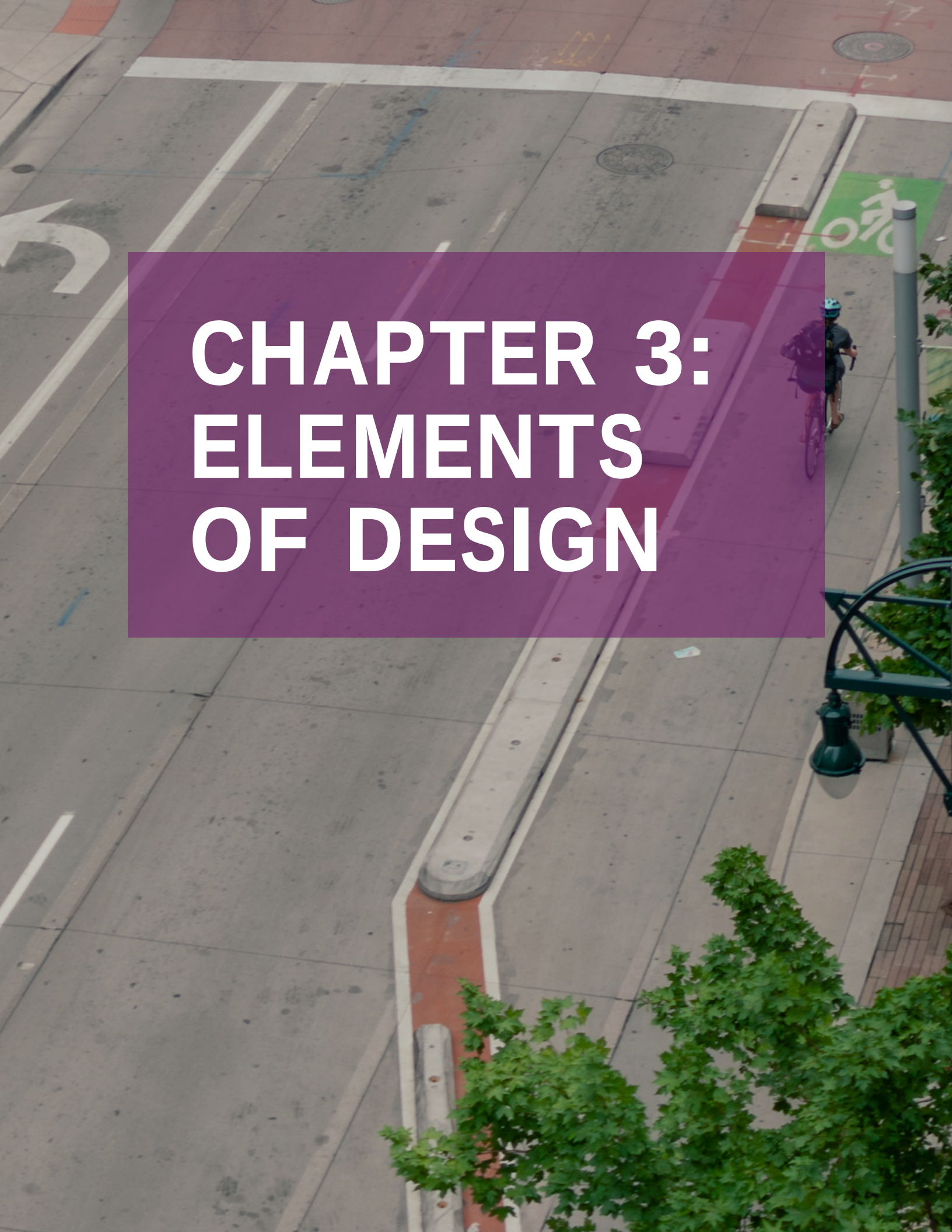


CHAPTER 3: ELEMENTS OF DESIGN

Chapter 3: Elements of Design

This chapter provides guidance for elements of design that are common to a wide range of pedestrian and bicycle facility types. These include design speed, sight distance, physical and operating width, alignment elements, and other considerations such as utilities, landscaping, and surface treatments.

Multimodal facility design controls are based on the physical and operating characteristics of various types of pedestrians and bicyclists and the vehicles and mobility devices they use to get around (see Table 3-13). Additionally, the interactions between users of shared facilities, such as shared use paths, must also be considered in the design. The pedestrian and bicycle physical characteristics include the user profile, size of the person and bicycle, and eye height, while the operating characteristics include the speed, reaction time, and braking ability.

Other elements of design that are important to the safe travel of people walking and bicycling include lighting, drainage, surface quality, placement of utilities and landscape elements, and geometric design strategies to reduce the number and severity of crashes at crossings. This chapter and later chapters discuss these common elements of design.

3.1 Design Flexibility and Engineering Judgement

Designers have significant flexibility making decisions regarding roadway design criteria. As defined by FHWA in its 2013 guidance memorandum, *Bicycle and Pedestrian Facility Design Flexibility,* [1] FHWA supports a flexible approach to bicycle and pedestrian facility design, including the use of multiple national guides and resources, such as those published by AASHTO, the National Association of City Transportation Officials (NACTO), and Institute of Transportation Engineers (ITE), to inform bicycle and pedestrian facility designs. FHWA explicitly "encourages agencies to appropriately use these guides and other resources to… go beyond the minimum requirements, and proactively provide convenient, safe, and context-sensitive facilities that foster increased use by bicyclists and pedestrians of all ages and abilities, and utilize universal design characteristics when appropriate."

Moreover, the AASHTO "Green Book" recommends a design process that encourages greater flexibility in design for all roadway projects, particularly for projects on existing roads. The goal is to address community and multimodal needs rather than to adjust existing roadway design features to meet nominal design criteria, if doing so is not necessary to address a documented safety need.

ODOT recognizes the need for flexibility in design. The preface in the L&D Manual Volume 1 states that designers must understand the context and the constraints of their project when selecting design criteria. L&D Manual Volume 1 describes the Performance-Based Project Development (PBPD) strategy that, like AASHTO, highlights the need to establish a Purpose and Need for a project and then evaluate options and design deviations that meet that Purpose and Need. The premise

is that the proposed improvements should be targeted and right-sized based on project-specific needs. The guidance provided in the MDG allows for flexibility by providing a range of values for most design criteria and including information for decision-making throughout the design process. Design flexibility is interrelated with PBPD, as both concepts make engineering decisions through an application of data, analysis, and engineering judgement.

Design flexibility should be used to prioritize the safety, comfort, and connectivity of people walking and biking. Applying design flexibility to multimodal design projects is not strictly defined and may require more conversations, considerations, exploration, and collaborating to develop answers to challenging design questions.

Common performance-based multimodal alternatives include fewer motor vehicle lanes (e.g., road diets) to provide space for bicyclist and pedestrian facilities, narrow lane widths where target motor vehicle speeds are low to enhance safety of all road users (especially pedestrians and bicyclists), and smaller corner radii to reduce the speeds of turning motorists where they conflict with pedestrians and bicyclists.

Documentation

When applying design flexibility, it is important to follow and document a clear process to determine the appropriate application of, or deviation from, design guidance in order to reach the solution. When implementing design decisions that are within the range of allowable values, but that perhaps use a higher than minimum value, these decisions should still be documented. All relevant design information, such as the selection of design user, design width selection, and others, should be documented in the project file.

3.2 Design Users

People who walk and bike are influenced by how comfortable they are using the street. The provision of low-stress, connected multimodal networks often improves a user's safety and accommodates walking and biking for a broader range of people. Often, when more people bicycle and walk, there is an increase in the safety of these user groups; this effect is commonly referred to as "safety in numbers."[2,3,4] The presence of more pedestrians and bicyclists encourages motorists to look for these street users where they are prevalent. As such, designing for the widest range of users will best accommodate the majority of users.

To design a multimodal transportation system that works for all people, the design process must account for basic factors such as safety and comfort, as well as human factors such as a person's physical abilities, experience, and their ability to perceive and react to potential conflicts.

In addition to the people navigating the system, it is necessary for designers to pay close attention to the mobility devices that users employ. Tools that enable or aid personal movement have physical and dynamic characteristics that should be considered in the design of the street. This focus on how people get around is the basis for identifying the design user profiles that inform key elements of design.

3.2.1. User Profiles

The design user profile varies based on the person's age, comfort, experience, skill, and abilities. It includes people who are familiar or unfamiliar with the area, and therefore the idea of "expectancy" is important to consider. User experiences develop over time and form a set of expectations, which allow the person to anticipate and plan for future events. This set of expectations is what enables people to respond to common situations in predictable and safe ways.

Designers should understand that a person's design profile may change in a single day. For example, a person who walks or bikes to work daily might be comfortable using a large arterial street with standard width sidewalks and bike lanes when traveling alone, but when traveling with children they may prefer to use lower volume or lower speed streets that have wider buffers from traffic, wider sidewalks, or a shared use path.

Pedestrians

There is no single "design pedestrian." Considerations when selecting facilities include walking and jogging speeds, spatial requirements, and mobility needs. The AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities provides details on these elements.

Designers should understand that pedestrians display a wide range of physical, cognitive, and sensory abilities. If a design works well for people with disabilities, it generally works well for those who do not have disabilities. It should be noted that disabilities are not a special condition of the few, but are ordinary occurrences that affect most people for at least some part of their lives. When facilities are designed for people of all ages and abilities, the transportation network can begin to safely and conveniently get everyone where they need to go.[5]

Designers should consider seniors and children, who typically walk slower, as the preferred user profile when assessing street crossings. A crossing that accommodates these slower users will naturally accommodate faster users. A person jogging should be considered as the preferred user profile when assessing sight distances for driveway crossings, the intersection of sidewalks and shared use paths, or other locations where pedestrians are not expected to yield to motorists or bicyclists. Designing sight distances for these faster users will naturally accommodate the slower pedestrian facility users. See Section 3.3 for design speeds.

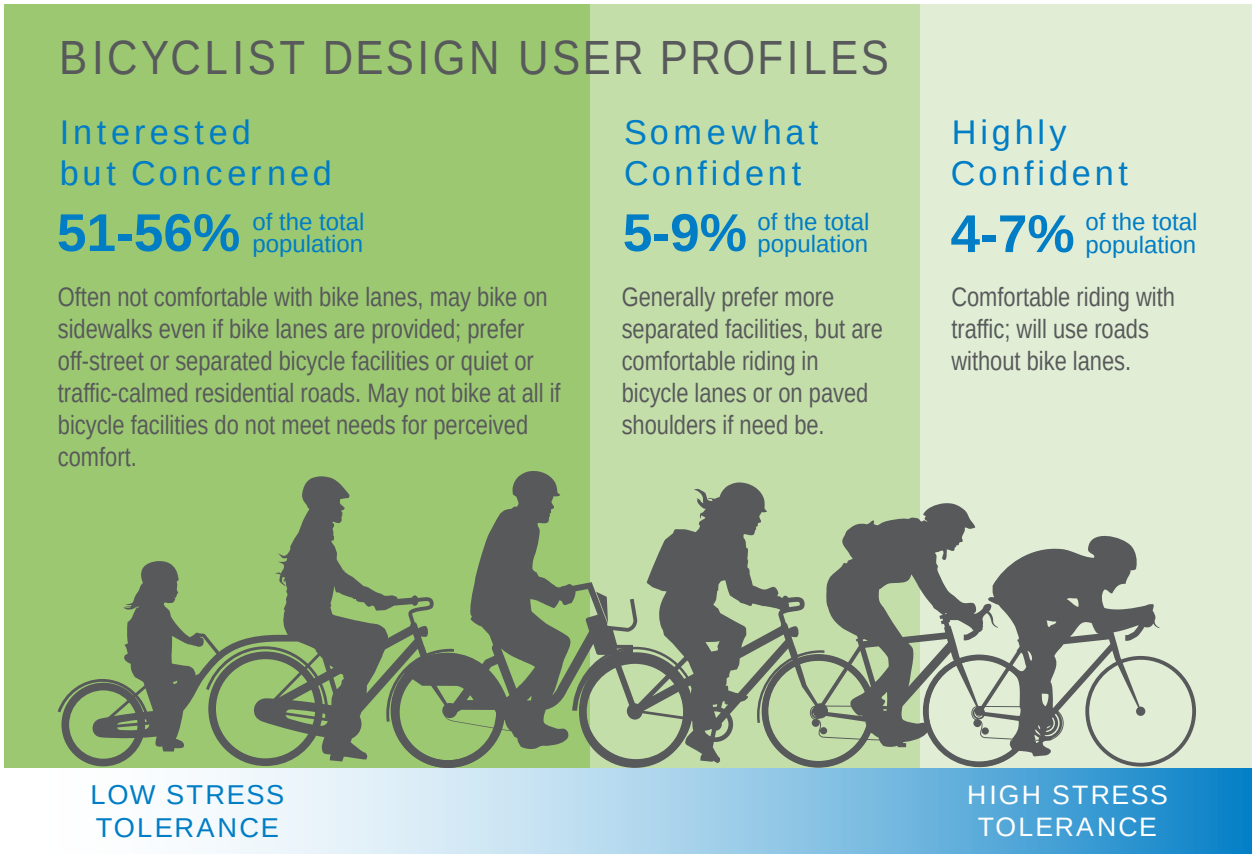
People bicycling

Of adults who have stated an interest in bicycling, research has identified three types of potential and existing bicyclist profiles (see Figure 3-1).[6] These bicyclist profiles consider a person's comfort level operating a bicycle with motorized traffic, bicycling skill and experience, age, and trip purpose. These user profiles can be used to inform bikeway design.

The Interested but Concerned Bicyclist profile should typically be used to choose a bikeway design, as this group represents 51 to 56 percent of the general population and is the largest of the bicyclist profiles. Members of this group bicycle less in many communities due to a lack of connected, low-stress bicycle networks; for the same reason, this group tends to bicycle more for recreation and is less comfortable riding for transportation . To maximize the potential for bicycling as a viable

transportation option, it is important to design facilities to meet the needs of the Interested but Concerned Bicyclist user, which will also naturally accommodate the Somewhat Confident and Highly Confident users.

Figure 3-1: Bicyclist Design User Profiles


BICYCLIST DESIGN USER PROFILES
Interested but Concerned
51-56% of the total population
Often not comfortable with bike lanes, may bike on sidewalks even if bike lanes are provided; prefer off-street or separated bicycle facilities or quiet or traffic-calmed residential roads. May not bike at all if bicycle facilities do not meet needs for perceived comfort.
Somewhat Confident
5-9% of the total population
Generally prefer more separated facilities, but are comfortable riding in bicycle lanes or on paved shoulders if need be.
Highly Confident
4-7% of the total population
Comfortable riding with traffic; will use roads without bike lanes.
LOW STRESS TOLERANCE
HIGH STRESS TOLERANCE

Designers should consider all likely users of a bicycle facility when establishing the various design controls. Common exceptions to using the adult bicyclist to establish design controls are:

- Using performance criteria associated with a pedestrian at street crossings where pedestrians will be crossing with bicyclists. This is common at shared use paths and at some bicycle boulevard crossings, which must be designed to ensure a pedestrian can safely cross the road at a typical walking speed.
- The heights and speeds of recumbent bicyclists or child bicyclists for the purposes of establishing sight distances or crossing times at intersections.
- Using a bicyclist pulling a trailer for the purposes of designing median crossing islands or queuing areas.

The performance characteristics of the typical adult bicyclist should generally be used to establish many geometric design controls because the adult bicyclist is typically the fastest and physically

largest user. Table 3-1 summarizes factors that may impact bicycling, such as acceleration, deceleration, and reaction time. The use of these values will generally ensure bicyclists of all abilities are accommodated on bikeways and roadways, but the context and expected use should also inform design decisions. For example, a shared use path with low pedestrian activity expected to be used for recreational bicycling may be a location where higher bicyclist design speeds are appropriate. See Section 3.3 for design speeds.

Table 3-1: Typical Adult Upright Bicyclist Performance Characteristics

Typical Adult Upright Bicyclist Performance Characteristics		
Feature	**Value**	**Recommended Design Value**
Speed, paved level terrain (2% max)	8.0-15.0 mph	15 mph design speed 8.0 mph (intersection crossing speed)
Speed, downhill[1]	For every 1% increase in downhill grade, speed is increased by 0.53 mph.	--
Speed, uphill[1]	For every 1% increase in uphill grade, speed is reduced by 0.90 mph.	--
Perception reaction time	1.0-2.5 seconds	1.5 seconds* (expected stop) 2.5 seconds* (unexpected stop)
Acceleration rate[2]	2.0-5.0 ft/s[1]	2.5 ft/s[1]
Coefficient of friction for braking, dry level pavement	0.1-0.8	0.32*[4]
Coefficient of friction for braking, wet level pavement	0.16*	0.16*
Deceleration rate (dry level pavement)[3]	8.0-10.0 ft/s[1]	10.0 ft/s[1]*
Deceleration rate for wet conditions	2.0-5.0 ft/s[1]*	5.0 ft/s[1]*

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[1] Parkin, J. & Rotheram, J. (2010) Design speeds and acceleration characteristics of bicycle traffic for use in planning, design and appraisal. Transport Policy, 17 (5). pp. 335-341. ISSN 0967-070X. Available from: http://eprints.uwe.ac.uk/20767

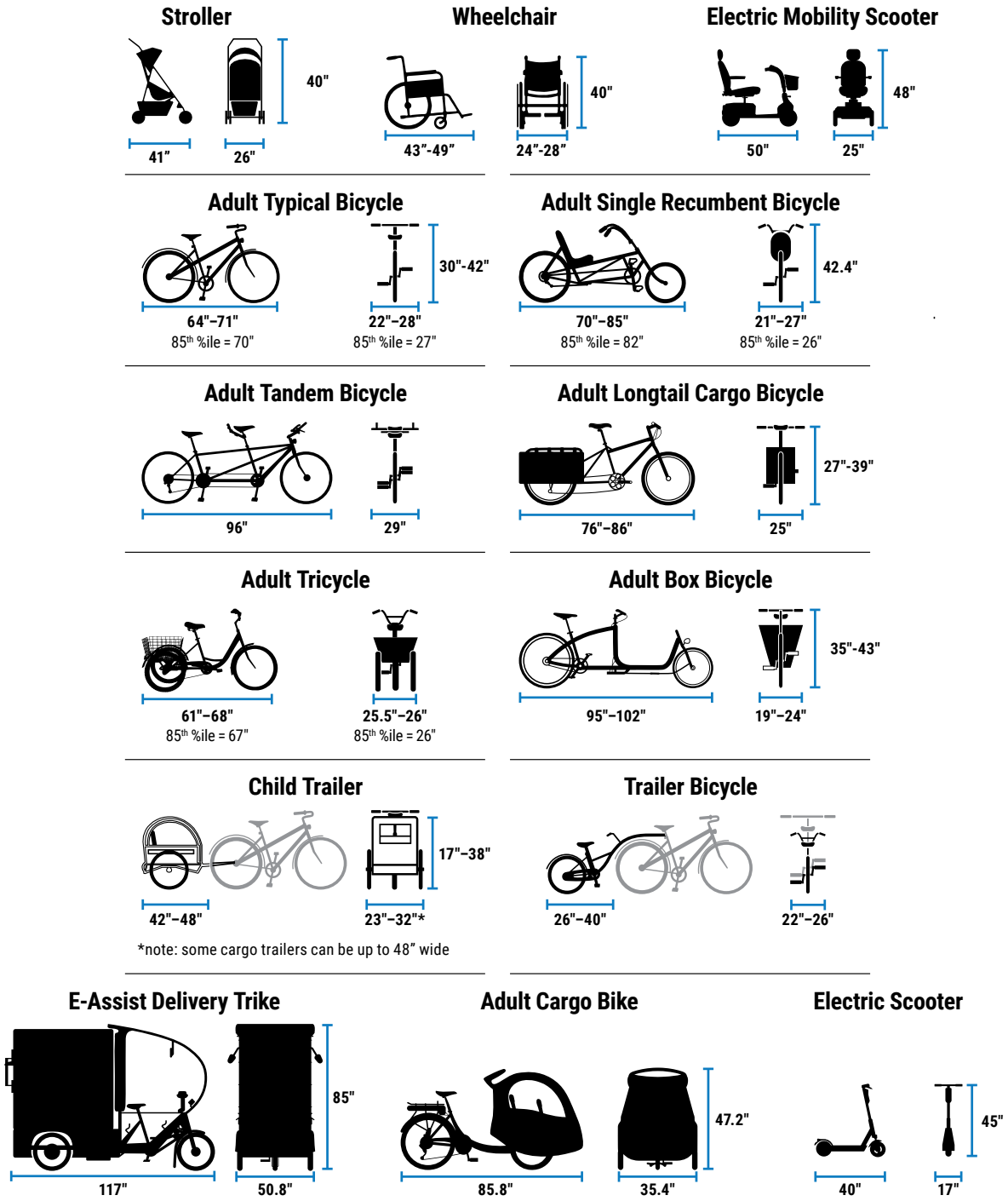
[2] Figiolizzi, M., Wheeler, N. & Monsere, C. (2013). Methodology for estimating bicyclist acceleration and speed distributions at intersections. Transportation Research Record: Journal of the Transportation Research Board, No. 2387, Transportation Research Board of the National Academies, Washington, D.C., pp. 66–75.

[3] Landis, B., Petritsch, T., Huang, H., & Do, A. (2004).Characteristics of Emerging Road and Trail Users and Their Safety. Transportation Research Record: Journal of the Transportation Research Board, (1878), 131-139.

3.2.2. Devices

Some of the types of devices that are commonly used on Ohio streets and trails are shown below in Figure 3-2. Typical variations in height, width, and length are noted. Although recommended facility widths for bike lanes, shared use paths, and sidewalks in the MDG generally address these devices, designers should be cognizant of the expected use of the longest and widest devices and should provide appropriate accommodations for the use of these devices.

Figure 3-2: Summary of Expected Design Vehicles and Dimensions



3.3 Design Speeds

Design speed is a fundamental design control used to determine various geometric features of a roadway or shared use path as well as some signal timing and street crossing parameters. Motor vehicle design speed consideration in multimodal design is discussed in Chapter 7 of this guide. Additional details for how speeds relate to the design of pedestrian and bicycle facilities is provided in Chapters 4, 5, and 6.

3.3.1. Pedestrians

Pedestrian speeds can vary based on physical ability, mobility devices used, age, and trip purpose, and in most cases range from 1 to 4 ft/s. 3.5 ft/s is the default assumed pedestrian design speed under most circumstances. 7.5 ft/s should be used as the assumed jogging speed of a pedestrian. These speeds are primarily used for determining pedestrian clearance intervals at signalized intersections but are also used for determining sight distances at some uncontrolled crossings. Additional information about accessible pedestrian signal design is available in the OMUTCD and Chapter 8. The OMUTCD provides for an extended pedestrian signal phase at accessible pedestrian signals and longer standard pedestrian signal phase lengths, which depend on the expected pedestrian speeds in a given intersection location.

The use of mobility devices can also affect walking speeds, and speeds can vary for people with disabilities, as shown in Table 3-2[7]. Designers should consider the frequency of users with mobility devices and disabilities and adjust design speeds accordingly.

Table 3-2: Mean Walking Speeds for Disabled Pedestrians and Users of Various Assistive Devices

Mean Walking Speeds for Disabled Pedestrians and Users of Various Assistive Devices	
Disability or Assistive Device	**Mean Walking Speed**
Cane or crutch	2.62 ft/s
Walker	2.07 ft/s
Wheelchair	3.55 ft/s
Immobilized knee	3.50 ft/s
Below-knee amputee	2.46 ft/s
Above-knee amputee	1.97 ft/s
Hip arthritis	2.24 to 3.66 ft/s
Rheumatoid arthritis	2.46 ft/s

Source: Human Factors in Traffic Safety

3.3.2. Bicyclists and Micromobility Users

Design speed is the speed used for the design of various geometric features of bicycle/micromobility facilities and street crossing parameters. It is important for designers to recognize that, similar to design for automobiles, the design speed for a bicycle facility should be set at the desired user speed, not necessarily the speed that a bicyclist or micromobility user is physically capable of achieving.

Bicycle design speed can range from 8 mph to 30 mph depending on the facility type and expected design user. By comparison, most micromobility devices have a maximum speed of 15 mph. The following values should be considered for the design speeds of different bicycle facility types:

- 15 mph on separated bikeway and high-volume shared use paths
- 18-30 mph on low-volume shared use paths (where peds < 30 percent)
- 15-20 mph on bicycle boulevards
- Posted speed for on-road facilities (though typically ≤ 30 mph)

Designers should consider the context of the facility and identify the appropriate design speed for the project. For example, a long-distance, low-volume shared use path may have a higher design speed between destinations, but it also may travel through higher-volume areas where either greater widths, separation between bicyclists and pedestrians, or lower design speeds may be appropriate.

3.4 Understanding Mutual Yielding

There are three key factors that should be considered when designing interactions between bicyclists, motorists, and pedestrians:

1. Motorists and bicyclists have a legal responsibility to yield to pedestrians in crosswalks. *[ORC 4511.46 Right-of-way of pedestrian within crosswalk [A]]*
2. Ohio Revised Code stipulates that a pedestrian may not suddenly leave any curb (or refuge median) and walk or run into the path of a vehicle that is so close that it is impossible for the motorist to yield. *[ORC 4511.46 Right-of-way of pedestrian within crosswalk [B]]*
3. Motorists have the legal responsibility to exercise due care to avoid colliding with any pedestrian or bicyclist. *[OPC 4511.46 Right of Way of rule at through highways, stop signs, yield signs and ORC 4511.13 Highway traffic signal indications]*

The result is a mutual yielding responsibility among motorists, bicyclists, and pedestrians, depending upon the timing of their arrival at an intersection. When designing intersections between pedestrian facilities and roadways, bikeways and roadways, or bikeways and pedestrian facilities, designers should understand the application of traffic control devices to communicate right of way and the laws regarding assignment of right of way for pedestrians and bicyclists (and other bicycle facility users).

The effectiveness of mutual yielding is dependent on the ability of each user to see and react to each other, which relies on providing clear sight lines between users (see Section 3.5), use of appropriate traffic control to communicate right of way, and sufficient lighting.

3.4.1. Zones: Recognition, Decision, Yield/Stop

In the case of permissive vehicular right and left turns across a bikeway, a turning motorist should yield to a through bicyclist unless the motorist is at a safe distance from the bicyclist to complete the turn at a reasonable speed prior to the bicyclist arriving at the conflict point. Bicyclists should yield to motor vehicles already within the intersection or so close that it is impossible to stop. Bicyclists and motorists must yield to (or stop for) pedestrians within a crosswalk. To facilitate these responsibilities, adequate sight distances and sight lines are needed between bicyclists, motorists, and pedestrians as they approach intersections. Sight distances should conform to sight distances established in Section 3.5 and L&D Manual Volume 1, Sections 200.

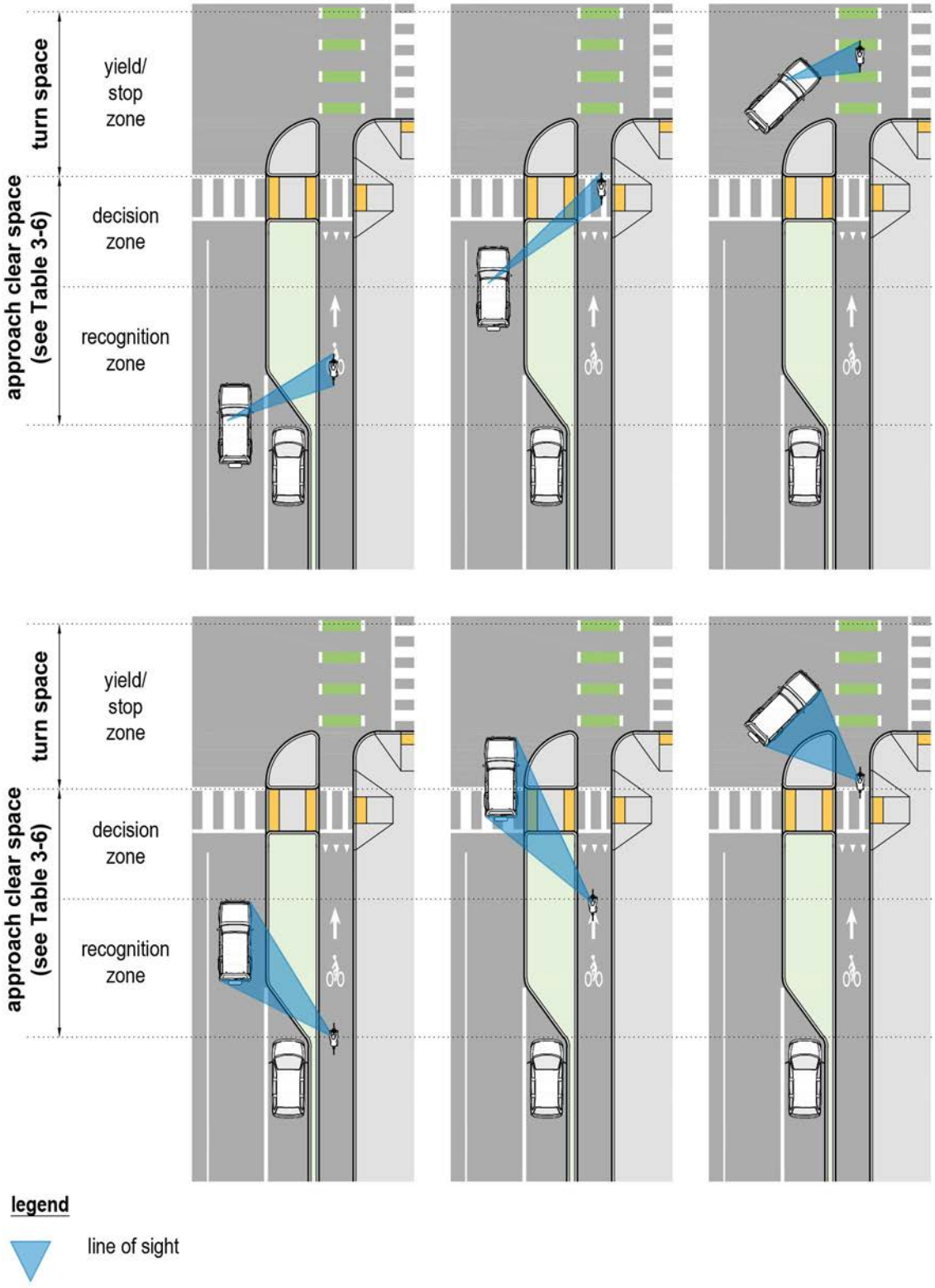
For all bikeway and pedestrian crossings, a design objective is to provide adequate sight distances and sight lines for each user to detect a conflicting movement of another user and to react appropriately as they approach a conflict point. The approach to a conflict point is composed of three zones:

1. Recognition zone - the approaching bicyclist, motorist, or pedestrian has an opportunity to see the other user(s) and evaluate their respective approach speeds.
2. Decision zone - the bicyclist, motorist, or pedestrian identifies who is likely to arrive at the intersection first and adjusts their speed to yield or stop if necessary.
3. Yield/stop zone - a space for the motorist or bicyclist to yield or stop, if necessary

At intersections with permissive turning movements where bicyclists and motorists are traveling in the same direction, there are two scenarios that occur depending upon who arrives first at the crossing. The ability for each user to respond accordingly is dependent upon the provision of the three zones mentioned above and depicted in Figure 3-3. The two yielding scenarios are:

- Turning Motorist Yields to (or Stops For) Through Bicyclists - This scenario occurs when a through moving bicyclist arrives or will arrive at the crossing prior to a turning motorist, who must stop or yield to a through bicyclist and pedestrians. For locations where bicyclists are operating on separated bike lanes and side paths, vertical elements near the intersection, including on-street parking, should be set back sufficiently for the motorist to see the approaching bicyclist and provide sufficient time to slow or stop before the conflict point.
- Through Bicyclist Yields to (or Stops For) Turning Motorist - This scenario occurs when a turning motorist arrives or will arrive at the crossing prior to, or at the same time as, a through moving bicyclist. This scenario can also occur when a bicyclist approaches after a motorist has yielded to other people crossing in the intersection and the crossing is clear for the motorist to proceed. The motorist may begin turning as the bicyclist approaches, requiring the bicyclist to slow and potentially stop while the motorist completes the turning movement.

Figure 3-3: Example of Mutual Yielding Zones Illustrating Intersection Sight Distance Case A



3.5 Sight Distance

The basic ability to see what lies ahead and to see intersecting users is fundamental to pedestrian and bicyclist safety, regardless of the facility type. Adequate sight lines and sight distances are needed to enable people walking, bicycling, and driving to slow, stop, or maneuver to avoid a conflict at all locations where they interact (e.g., street and roadway intersections, driveways, and alleys). Adequate sight lines should also be provided between bicyclists and pedestrians where they interact at crosswalks, intersections, bus stops, and other conflict areas.

3.5.1. Stopping Sight Distance

Adequate motor vehicle stopping sight distance is important for the safety of pedestrians and bicyclists who must cross roadways. Refer to L&D Manual Volume 1, Section 201.2 for procedures for determining motor vehicle stopping sight distances.

Bicycle stopping sight distance is the distance needed to bring a bicycle to a fully controlled stop. It is a function of the user's perception and brake reaction time, the initial speed, the coefficient of friction between the wheels and the pavement, the braking ability of the user's equipment, and the grade. Table 3-3 provides the formula for minimum stopping sight distance. A perception/reaction time of 2.5 seconds should typically be used to calculate stopping sight distance, though 1.5 seconds may be appropriate where bicyclists have an expectation of potential conflicts, such as approaching intersections or in urban areas. The sight distance for bicyclists should typically be measured from 3.83 ft. above the ground to accommodate recumbent bicyclists.

Table 3-3: Minimum Stopping Sight Distance

Minimum Stopping Sight Distance		
$S = \frac{V^2}{30(f \pm G)} + 1.47\ Vt$		
Where:		
S	=	stopping sight distance (ft)
V	=	velocity (mph)
f	=	coefficient of friction (0.16 for a typical bike in wet conditions)
G	=	absolute value of grade (ft/ft) (rise/run)
t	=	perception / reaction time (1.5 seconds for expected stops, 2.5 seconds for unexpected stops)

Note: $\pm$ = negative traveling downhill, positive uphill

Table 3-4 and Table 3-5 indicate the minimum stopping sight distances based on speed and grade for 2.5 and 1.5 seconds of perception/reaction time respectively. Some values are omitted from these tables because they may be impractical or unachievable due to the steep grades. In those instances, designers should recognize that bicyclists may be traveling faster or slower than the typical design speed and adjust their design assumptions accordingly.

Table 3-4: Minimum Stopping Sight Distance vs. Grades for Various Design Speeds—2.5 Second Reaction Time

Stopping Sight Distance (ft) Based on Speed and Grade for a 2.5 Second Perception-Reaction Time											
Speed (mph)	Grade (Positive indicates ascending)										
	-10%	-8%	-6%	-4%	-2%	0	2%	4%	6%	8%	10%
10				65	61	58	55	53	52	51	50
11				74	69	66	63	61	59	57	56
12				84	78	74	71	68	66	64	62
15			130	118	109	102	97	93	89	86	84
18	246	201	174	156	143	134	126	120	115	111	108
20	296	240	207	185	169	157	148	140	134	129	
25	440	353	300	266	241	222	208	196	187		
30	611	486	411	361	325	298	277	260			

Table 3-5: Minimum Stopping Sight Distance vs Grade for Various Design Speeds—1.5 Second Reaction Time

Stopping Sight Distance (ft) Based on Speed and Grade for a 1.5 Second Perception-Reaction Time											
Speed (mph)	Grade (Positive indicates ascending)										
	-10%	-8%	-6%	-4%	-2%	0	2%	4%	6%	8%	10%
10				50	46	43	41	39	37	36	35
11				58	53	49	47	44	43	41	40
12				66	61	56	53	50	48	46	45
15			108	96	87	80	75	71	67	64	62
18	220	175	148	130	117	107	100	94	89	85	81
20	267	211	178	155	139	128	118	111	105	100	
25	403	316	264	229	204	185	171	159	150		
30	567	442	367	317	281	254	233	216			

3.5.2. Intersection Sight Distance

L&D Manual Volume 1, Section 201 establishes a range of recommended sight triangles that correspond to requirements for motorists to have sufficient space to identify, react, and potentially yield to other traffic at an intersection based on the traffic control applied at the intersection. Applying the sight triangle requirements provided in L&D Manual Volume 1, Section 201 will result in sufficient sight distance for some bicycle facilities, such as shared lanes and conventional bike lanes. Designers should consider the placement of bicyclists (often closer to the edge of the road in a shared lane environment or in a conventional bike lane) and their design speed when determining the sight triangles for these types of bicycle facilities.

Bike Case A: Right-Turning Motorist Across Separated Bike Lane or Side Path

Figure 3-3 depicts Bike Case A, which applies when a motorist is making a right turn across a separated bike lane or side path and bicyclists have concurrent through movement.

In this case the motorist will be decelerating for the right turn approaching the intersection. The motorist's turning speed is controlled by the intersection corner geometry and width of the receiving roadway. Table 3-6 identifies the minimum approach clear space, measured from the point of curvature of the motorist's effective turning radius, which represents the location where the motorist will have decelerated to the turning speed; this location may or may not be the curb line point of curvature. Clear space provides the necessary sight lines between motorists and bicyclists to yield (or stop) as appropriate. For locations with two-way separated bike lanes or side paths, additional approach clear space is not typically required, as the recognition zone between the counterflow bicyclist movement and the right-turning motorists should exceed the recommended sight distances. Approach clear space may be increased to account for steeper slopes or higher speeds for bicyclists.

Table 3-6: Intersection Approach Clear Space by Vehicular Turning Design Speed

Effective Vehicle Turning Radius	Target Vehicular Turning Speed	Approach Clear Space
<18 ft	<10 mph*	20 ft
18 ft	10 mph	40 ft
25 ft	15 mph	50 ft
30 ft	20 mph	60 ft
≥50 ft	25 mph	70 ft

*most low volume driveways and alleys

Bike Case B: Left-Turning Motorist Across Separated Bike Lane or Side Path

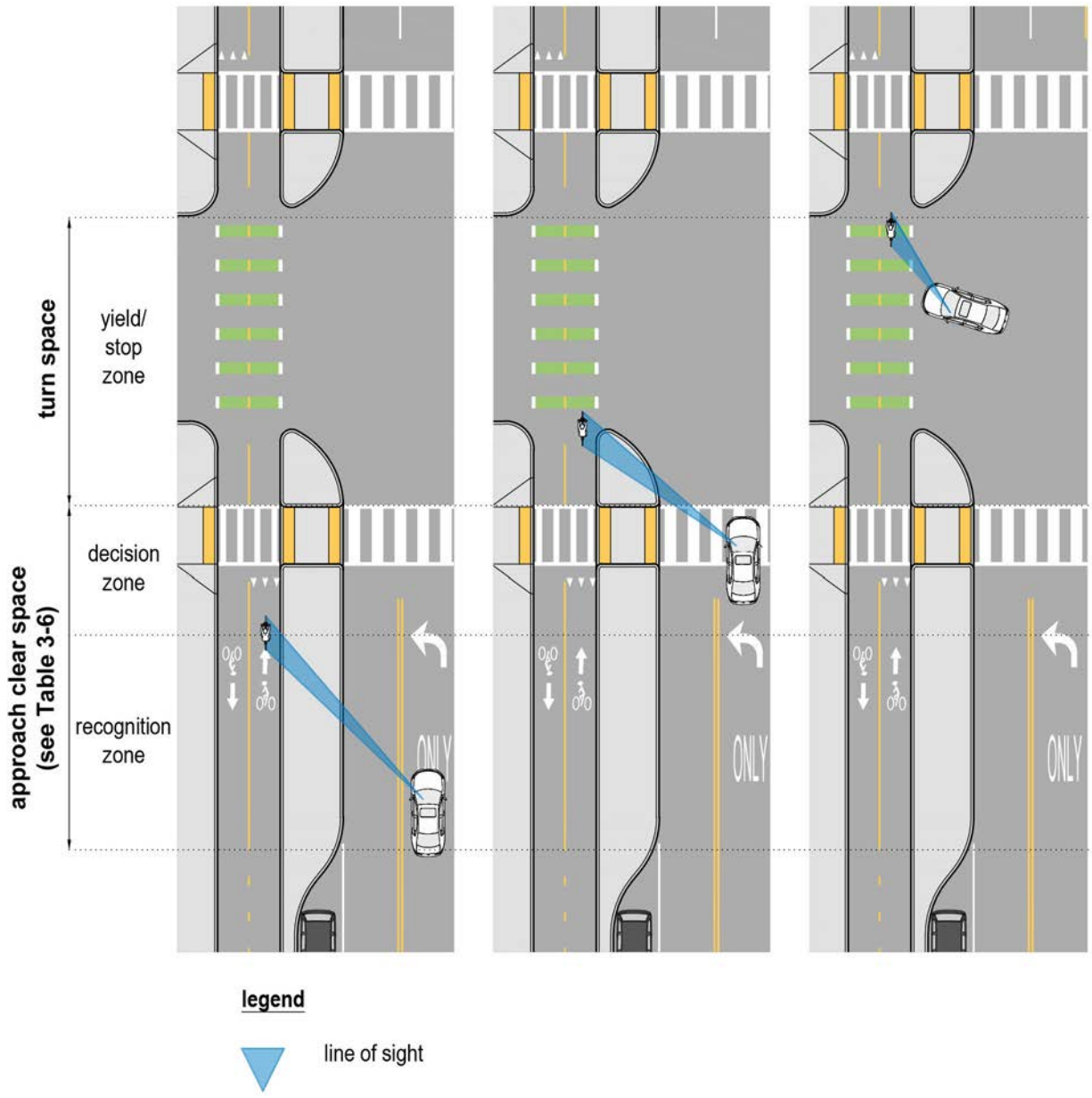
This case applies when a motorist is making a permissive left turn at a traffic signal or from an uncontrolled approach (e.g., a left turn from an arterial onto a local street or driveway). On one-way streets with a left-side separated bike lane or side path, this case has the same operational dynamics and approach clear space requirements as Bike Case A since the left-turning motorist will be turning adjacent to the separated bike lane. On two-way streets with a left-side separated bike lane or side path, there are two sight lines that should be maintained. A left-turning motorist approaching a turn needs a line of sight to bicyclists approaching from the same direction (see Figure 3-4). Table 3-6 identifies the minimum approach clear space based on the effective turning radius for the left-turning motorist. The provision of Bike Case A for motorists making a right-turn across a two-way bikeway will already provide the necessary line of sight between a left-turning motorist and a bicyclist approaching from the opposite direction.

On streets with two-way traffic flow, the operational dynamic of a motorist looking for gaps in traffic creates unique challenges that cannot be resolved through improving sight distance. This is a challenging maneuver because the motorist is primarily looking for gaps in oncoming motor vehicle traffic and is less likely to scan for bicyclists approaching from behind. Unlike for Bike Case A or Bike Case B on one-way streets where the motorist is decelerating towards the crossing, the motorist in this case will be accelerating towards the crossing once they perceive a gap in traffic. This creates a higher potential for conflicts on roads with the following:

- High traffic volumes and multiple lanes
- Higher operating speeds
- High left turn volumes

Where it is not feasible to eliminate high speed and high-volume conflicts through signalization, turn prohibitions, or other traffic control, it may be necessary to reevaluate whether a side path or two-way separated bike lane is appropriate at the location, or provide an adequate motorist yield zone that allows the motorist to complete the turn while still yielding to crossing pedestrians or bicyclists (see Section 6.5.2).

Figure 3-4: Intersection Sight Distance Bike Case B



Bike Case C: Motorist Crossing of a Separated Bike Lane or Side Path/ Shared Use Path

This case applies when a motorist crosses a separated bike lane or side path and is similar to the cases in the *Guide for the Development of Bicycle Facilities* where a motorist crosses a bike lane or a mid-block path. The bike lane case is expanded upon below, including near-side and far-side intersection scenarios.

Bike Case C1 – Near-Side Crossing

This case applies when a motorist crosses a near-side separated bike lane or side path before continuing straight or turning at an intersection.

The two potential design scenarios are as follows:

Scenario #1: Two-Stage Crossing

In this scenario, the motorist will first assess the bicycle conflicts, then move forward and assess motor vehicle conflicts (i.e., designers should perform two calculations from two different locations) as shown in Figure 3-5. Similar to when a motorist moves forward after assessing pedestrian conflicts, when the motorist moves forward, they might block the bikeway to look for gaps in traffic. The equation in Table 3-7 should be used to calculate the departure sight triangle between a passenger vehicle and the bikeway using a time gap (t_g) of 5.5 seconds for the motorist to clear the bikeway. This time gap uses an assumption that the vertex (decision point) of the departure sight triangle is 10 ft. from the edge of bikeway and the bikeway width is no wider than 14 ft. The appropriate sight distance from L&D Manual Volume 1, Section 201.3.2 should then be used to calculate departure sight triangle between the motorist and the intersecting motorist travel lanes.

Table 3-7: Bike Case C Intersection Sight Distance

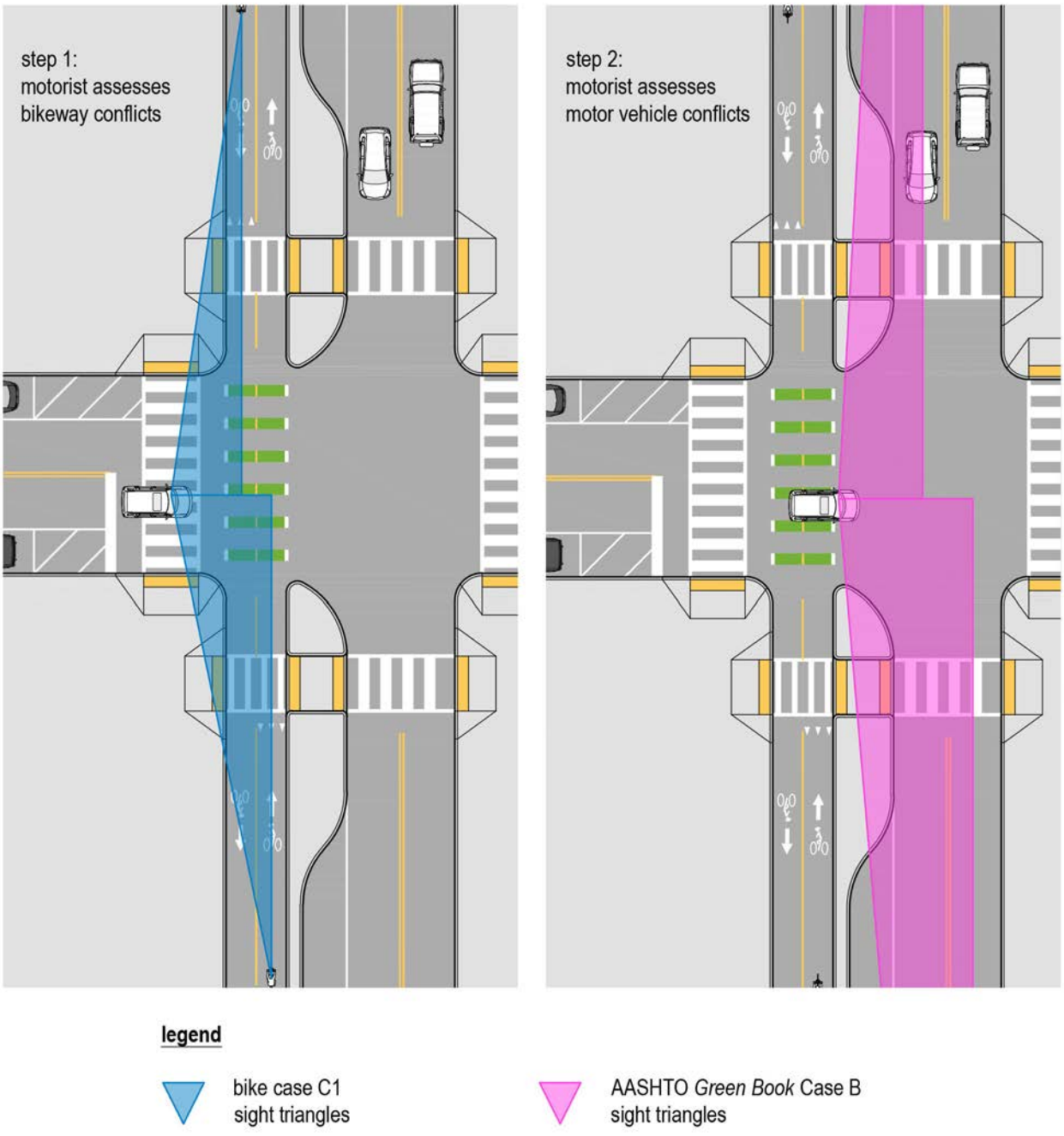
Bike Case C Intersection Sight Distance		
$ISD_{bike}=1.47\ V_{bike}\ t_g$		
Where:		
ISD_{bike}	=	intersection sight distance (length of the leg of sight triangle along the bikeway) (ft)
V_{bike}	=	design speed of bikeway (mph)
t_g	=	time gap for passenger vehicle to cross bikeway (s)

Scenario #2: Single Crossing

In this scenario, the motorist assesses both the bikeway conflicts and motor vehicle conflicts from one stopped location, then performs the turning movement when there is a sufficient gap in both the bikeway and motor vehicle traffic (see Figure 3-6). This scenario may be appropriate in locations where the motorist would otherwise block the bike facility for extended periods of time or where bicycle volumes or motorist volumes are anticipated to be high. The equation in Table 3-7 should be used to calculate the departure sight triangle between a passenger vehicle and the bikeway using a time gap (t_g) of 4 seconds for the motorist to clear the bikeway. This time gap uses

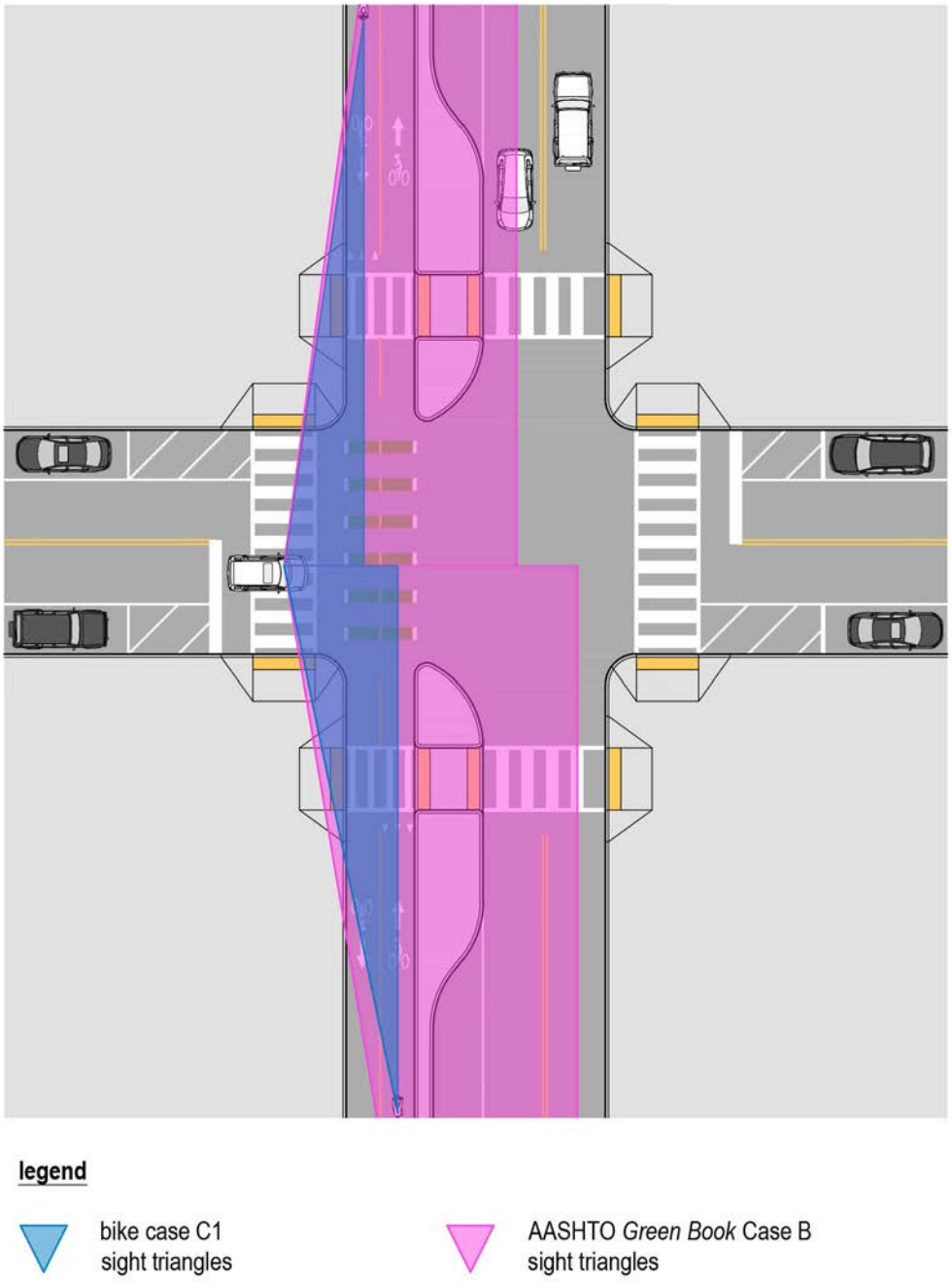
an assumption that the vertex (decision point) of the departure sight triangle is 10 ft. from the edge of bikeway and the bikeway width is no wider than 14 ft. The vertex of the departure triangle between the motorist and the intersecting motorist travel lanes will remain the same, but designers will need to adjust the typical time gap for the appropriate sight distance from L&D Manual Volume

Figure 3-5: Intersection Sight Distance Bike Case C1 – Two-Stage Crossing Scenario



1, Section 201.3.2 to account for the longer distance that the motorist will traverse. As shown in Figure 3-6, the provision of the motorist intersection sight distance will often accommodate the sight distance along the bikeway.

Figure 3-6: Intersection Sight Distance: Bike Case C1 – Single Crossing Scenario



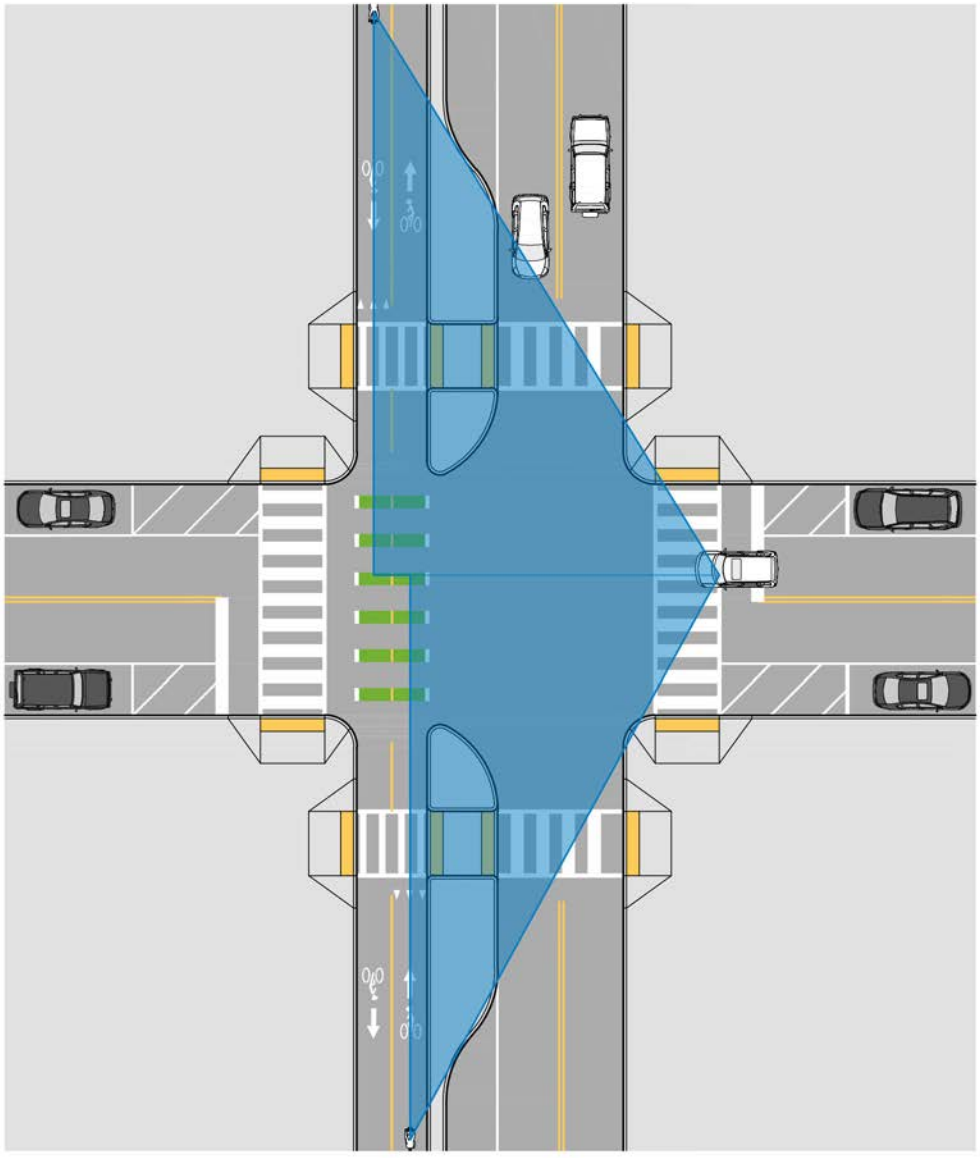
Bike Case C2 – Far-Side Crossing

This case applies when a motorist crosses a far-side separated bike lane or side path (see Figure 3-7).

Where both the motorist and bikeway approaches are stop-controlled, providing a line of sight between the stopped motorist and the stopped bikeway user is appropriate.

Where the motorist approach is stop-controlled and the bikeway crossing is uncontrolled, the intersection sight distance described in L&D Manual Volume 1, Section 201.3.2.3 should be used to calculate departure sight triangle between the motorist and the intersecting bikeway. The bikeway

Figure 3-7: Intersection Sight Distance Case C2



legend

sight triangles

design speed should be used in the intersection sight distance triangle calculation. The bikeway width and street buffer width should be converted to equivalent lane widths to adjust the time gap (t_g) for the crossing of the roadway and the bikeway. In constrained situations, at a minimum the stopping sight distance (for bicyclists) should be provided to allow a bicyclist to slow or stop if a vehicle encroaches into the bikeway.

As with Bike Case B, this case creates a challenging dynamic that is often difficult to resolve by increasing the size of the sight triangle. In urban areas, it may be difficult to increase the sight triangle enough to provide the intersection sight distance to judge gaps that allow a motorist to cross all the travel lanes as well as the separated bike lane/side path on the opposite side of the road. As such, designers should consider the frequency of through movements at these types of intersections and provide either traffic control devices or adequate sight distance (i.e., minimum stopping sight distance) for bicyclists to see and react to a crossing vehicle and stop if necessary. It may be appropriate to restrict these through motorist movements where traffic control devices or sight distances are inadequate.

Case C3 – Mid-Block Shared Use Path Crossing of a Roadway

If either the roadway approach or the shared use path approach is yield-controlled, adequate sight lines should be provided for a traveler on the yield-controlled approach to slow, stop, and avoid a user on the other approach. The length of the roadway leg of the sight triangle is based on a bicyclist's ability to reach and cross the roadway if they do not see a potential vehicle conflict and have just passed the point where they can execute a stop without entering the intersection (see Figure 3-8 and Table 3-8). See Section 3.5.1 for additional information on bicyclist stopping sight distance.

Figure 3-8: Mid-Block Shared Use Path Crossing Sight Triangle

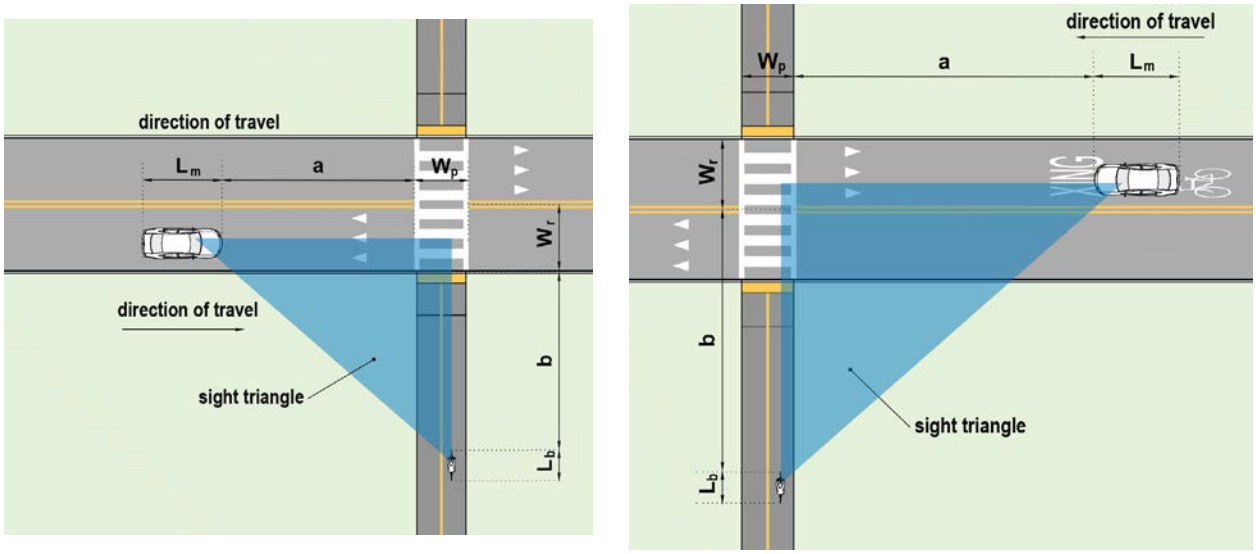


Table 3-8: Roadway Sight Triangle Equation

Roadway Sight Triangle Equation		
$t_a = \frac{S}{1.47V_{path}}$	$t_g = t_a + \frac{W_r + L_b}{1.47V_{path}}$	$a = 1.47\ V_{road} t_g$
Where:		
t_g	=	travel time to reach and clear the road (s)
a	=	length of leg sight triangle along the roadway approach (ft)
t_a	=	travel time to reach the road from the decision point for a path user that doesn't stop (s).
W_r	=	width of the lane to be crossed by the path user (ft)
L_b	=	Typical bicycle length = 6 ft (see Chapter 2 for other bicycle lengths)
V_{path}	=	design speed of the path (mph)
V_{road}	=	design speed of the road (mph)
S	=	stopping sight distance for the path user traveling at design speed (ft) (See table 5-1)

Similar to the roadway approach, the length of the path leg of the sight triangle is based on a motorist's ability to reach and cross the junction if they do not see a potentially conflicting path user approaching and they have passed the point where they can execute a stop without entering the intersection. The length of the sight triangle along the path leg of each approach is given in Table 3-9.

Table 3-9: Path Sight Triangle Equation

Path Sight Triangle Equation		
$t_a = \frac{1.47\ V_e - 1.47\ V_b}{a_i}$	$t_g = t_a + \frac{W_p + L_m}{1.47 V_e}$	$b = 1.47\ V_{path} t_g$
Where:		
t_g	=	travel time to reach and clear the path (s)
b	=	length of leg sight triangle along the path approach (ft)
t_a	=	travel time to reach the path from the decision point for a motorist that doesn't stop (s). For road approach grades that exceed 3 percent, value should be adjusted in accordance with AASHTO's A Policy on Geometric Design of Highways and Streets
V_e	=	speed at which the motorist would enter the intersection after decelerating (mph) (assumed $0.6V_{road}$)
V_b	=	speed at which braking by the motorist begins (mph) (same as road design speed)
a_i	=	motorist deceleration rate (ft/s^2) on intersection approach when braking to a stop not initiated (assumed - 5.0 ft/s^2)
W_p	=	width of the crosswalk to be crossed by the motorist (ft)
L_m	=	length of the design vehicle (ft)
V_{path}	=	design speed of the path (mph)
V_{road}	=	design speed of the road (mph)
Note: This table accounts for reduced vehicle speeds per standard practice in AASHTO's A Policy on Geometric Design of Highways and Streets.		

Table 3-10 provides minimum distances for the length of the path and roadway legs of the sight triangle for flat terrain with basic assumptions about the site conditions and vehicle characteristics. If the appropriate approach sight distances cannot be provided, a more restrictive control should be used.

A key consideration at mid-block crossings for shared use paths is the need to consider mutual yielding dynamics at crosswalks (see Section 3.5). Where the path is stop- or yield-controlled, the departure sight distance for the path should be based on the slowest user who will have exposure to crossing traffic. This is typically the pedestrian. Under certain conditions it may be desirable to use a slower walking speed that is appropriate for seniors and children to calculate departure sight distance for the path crossing. Regardless of intersection sight triangle lengths, roadway and path approaches to an intersection should provide sufficient stopping sight distance so that motorists and bicyclists can avoid obstacles or potential conflicts within the intersection.

Table 3-10: Length of Path and Roadway Sight Triangle (ft)

Length of Path and Roadway Sight Triangle (ft) - Bike Case C3						
Bike Speed (mph)	**Roadway Speed (mph)**					
	15	**20**	**25**	**30**	**35**	**40**
10	96 / 58	128 / 59	160 / 63	192 / 68	224 / 74	255 / 81
12	98 / 70	131 / 70	164 / 75	197 / 82	230 / 89	262 / 97
15	105 / 87	140 / 88	174 / 94	209 / 102	244 / 111	279 / 122
18	112 / 105	150 / 106	187 / 113	225 / 122	262 / 134	300 / 146
20	118 / 116	157 / 117	197 / 125	236 / 136	275 / 149	315 / 162
25	133 / 145	178 / 147	222 / 156	266 / 170	311 / 186	355 / 203
30	149 / 174	199 / 176	249 / 188	298 / 204	348 / 223	398 / 244

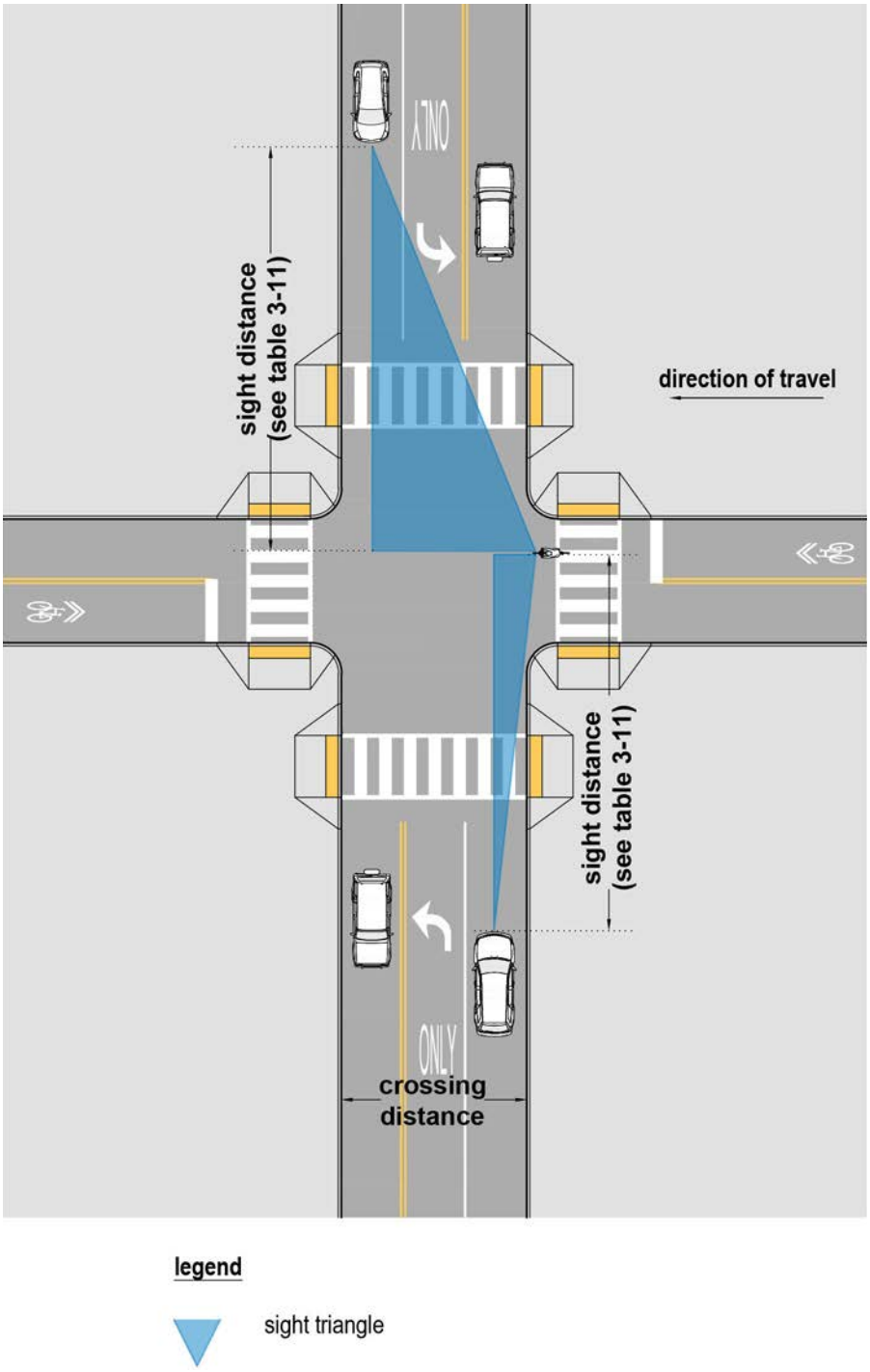
a / b
a = sight distance (ft) along roadway
b = sight distance (ft) along path

Assumptions: Bicycle reaction time = 1.5 sec
Width of path = 10 ft to 11 ft
Width of road lane = 11 ft to 12 ft
Length of bicycle = 6 ft
Length of motor vehicle = 18 ft
Grade = -2% to 0%

Bike Case D – Bicyclist Crossing from a Minor Road

Where a stop-controlled roadway intersects an uncontrolled roadway, bicyclists must judge the speed of, and gaps in, approaching motor vehicle traffic from their location at the edge of the roadway (see Figure 3-9). Providing the minimum stopping sight distance for the motorist on the uncontrolled roadway approach will allow the motorist sufficient time to exercise due care to slow

Figure 3-9: Bicyclist Crossing from a Minor Road Case D



or stop for the crossing bicyclist who may still be in the intersection. Table 3-11 provides the length of the departure sight triangle along the roadway to allow the bicyclist enough time to judge a gap in traffic and complete a full crossing of the roadway without a motorist needing to slow or stop. The table assumes a bicyclist with a:

- design acceleration of 2.5 ft/s^2,
- maximum speed of 8 mph to account for a slow bicyclist, and
- bicycle length of 6 ft.

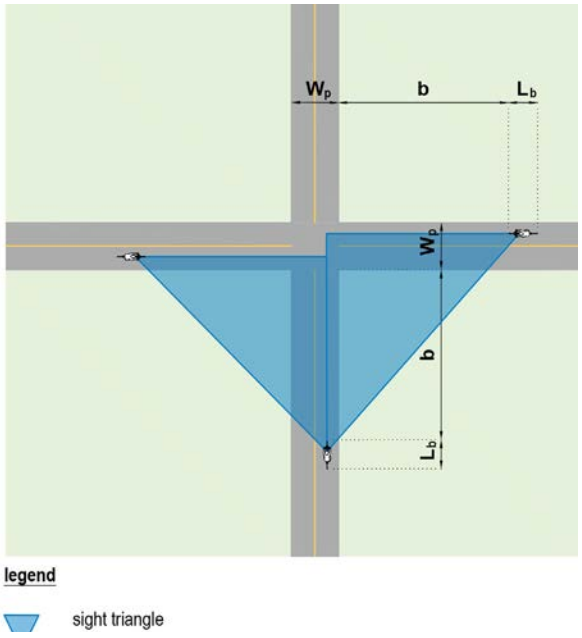
Table 3-11: Bicyclist Sight Distance Crossing from a Minor Road Case D

Bicyclist Sight Distance (ft) Crossing from a Minor Road						
Crossing Distance (ft)	Speed of Roadway to be Crossed (mph)					
	20	25	30	35	40	45
10	149	187	224	261	299	336
15	165	206	247	288	329	370
20	178	223	267	312	356	401
25	191	238	286	333	381	429
30	202	252	303	353	404	454
35	216	270	324	378	431	485
40	228	285	342	399	456	514
45	241	301	361	421	481	542
50	253	317	380	443	506	570
55	266	332	399	465	531	598
60	278	348	417	487	556	626

Bike Case E – Shared Use Path Crossing of another Shared Use Path

As shown in Figure 3-10, if a shared use path intersects another shared use path and the intersection is uncontrolled, sight triangles similar to the yield condition described in Bike Case C3 above should be provided. However, both legs of the sight triangle should be based on the stopping sight distances of the paths. Use the equation in Table 3-9 or value "b" from Table 3-10 for both legs of the sight triangle. If sufficient sight distance cannot be provided, traffic control, such as a stop sign or shared use path roundabout, must be considered.

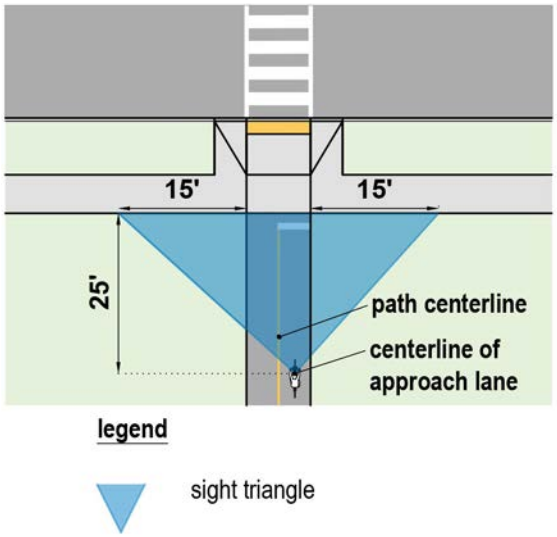
Figure 3-10: Bicyclist Crossing a Shared Use Path from a Shared Use Path Case E



Bike Case F – Bikeway Crossings of Walkways

At an intersection of a stop-controlled shared use path and a walkway, a clear sight triangle extending at least 15 ft. along the walkway and 25 ft. along the shared use path should be provided to ensure clear lines of sight between the path and walkway users (see Figure 3-11).

Figure 3-11: Minimum Path-Walkway Sight Triangle



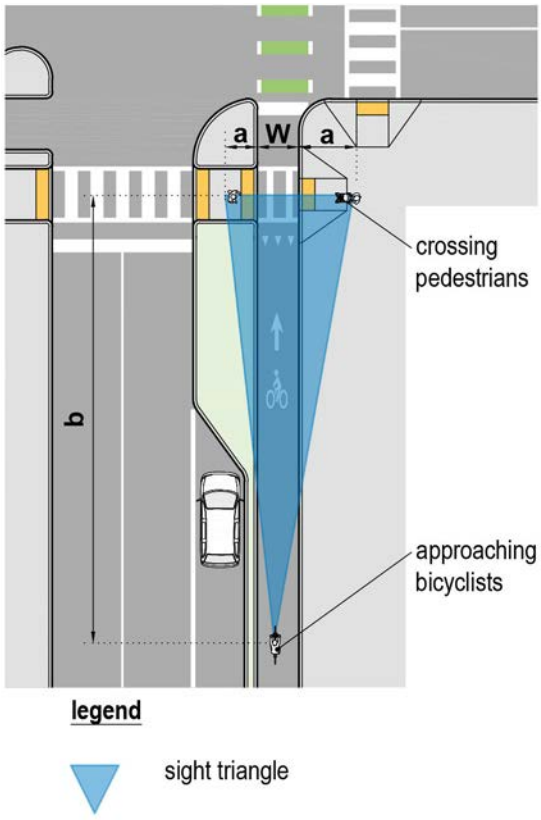
At an intersection of a walkway and an uncontrolled shared use path, or where a pedestrian crosses a separated bike lane (e.g., to cross a street, access a crossing island, or floating bus stop), the length of the clear sight triangle along the bikeway should be determined using the equation presented in Table 3-12 or the minimum stopping sight distance (see Table 3-3), whichever is smaller. The length of the sight triangle along the intersecting walkway should be determined using the equation presented in Table 3-12 or if a curb ramp is present the length should be the distance between the curb line and the pedestrian landing at the top of the curb ramp (see Figure 3-12). The clear sight triangle provides sufficient time for pedestrians walking (3.5 ft/s) or running (12.5 ft/s) to judge gaps in approaching bicycle traffic and for bicyclists to perceive the presence of a pedestrian and slow or stop as necessary. If pedestrian crossings of bikeways is unexpected, signs may also be provided to warn bicyclists of the pedestrian crossing.

Table 3-12: Pedestrian and Bicyclist Intersection Sight Distance

Pedestrian and Bicyclist Intersection Sight Distance		
$b = 1.47 \times V \left(\frac{W}{s_p} + t_s\right)$		$a = s_p \times t_s$
where:		
b	=	length of sight triangle along bicycle facility approach (ft)
V	=	design speed of bicycle facility (mph)
a	=	length of sight triangle along walkway approach (ft)*
s_p	=	speed of pedestrian (ft/s) s_p (walking) = 3.5 (ft/s) s_p (running) = 12.5 (ft/s)
t_s	=	pedestrian reaction and stopping time default = 2.0 (s)
W	=	width of bicycle facility (ft)

* If a curb ramp is present for the walkway, the length of *a* should be the distance between the curb line and the level landing at the top of the curb ramp.

Figure 3-12: Pedestrian Crossing Shared Use Path or Separated Bikeway (shown) Sight Triangle



3.6 Geometric Design Elements

Key controls in geometric design for bicycle and pedestrian facilities are directly related to the characteristics of the various users of the facilities and the characteristics of motor vehicles where the facilities interface with roadways. The L&D and other adopted policies adequately covers the characteristics of motor vehicles and that information is not repeated here. However, in some cases relevant motor vehicle characteristics from the AASHTO "Green Book" are noted or are used in developing bicycle and pedestrian facility geometric design guidance.

As discussed in Section 3.6.1, the physical dimensions and operating characteristics of people walking and bicycling vary considerably. By choosing geometric design values that fit the upright adult bicyclist, most other users of the bicycle facility will be accommodated. For example, a railing designed to protect an adult bicyclist will protect a shorter child bicyclist. Providing designs that serve the operating space of the adult bicyclist will accommodate the most common design user operating in bicycle facilities, except for some vehicles and equestrians that may use shared use paths (see Chapter 6).

3.6.1. User Operating Space and Facility Widths

In addition to establishing the user profile and performance characteristics of people walking and bicycling, designers should understand the principles of operating space. When developing design parameters for sidewalk and bikeway widths, designers should consider the space occupied by the user and whatever device they may have, their operating space, and any additional shy space to vertical objects or obstructions adjacent to them (See Section 3.6.2). These combined operating and shy spaces are used to establish width requirements for sidewalk facilities, bicycle facilities, and shared use paths as discussed in Chapters 4, 5, and 6.

Physical Space

The figures in Section 3.2.2 shows that there are multiple types of bicycles and other devices for consideration. Though Section 3.2.1 notes that there is not a single design pedestrian, for the purpose of defining typical physical space dimensions, a typical adult in a wheelchair should be assumed for pedestrians:

- 3 ft. width
- 4 ft. length

When facilities include bicyclists, it is recommended that the design user be an adult bicyclist with a trailer in order to accommodate most users. The following minimum physical space dimensions should be used:

- 2.5 ft. width
- 10 ft. length
- 7 ft. height

Operating Space

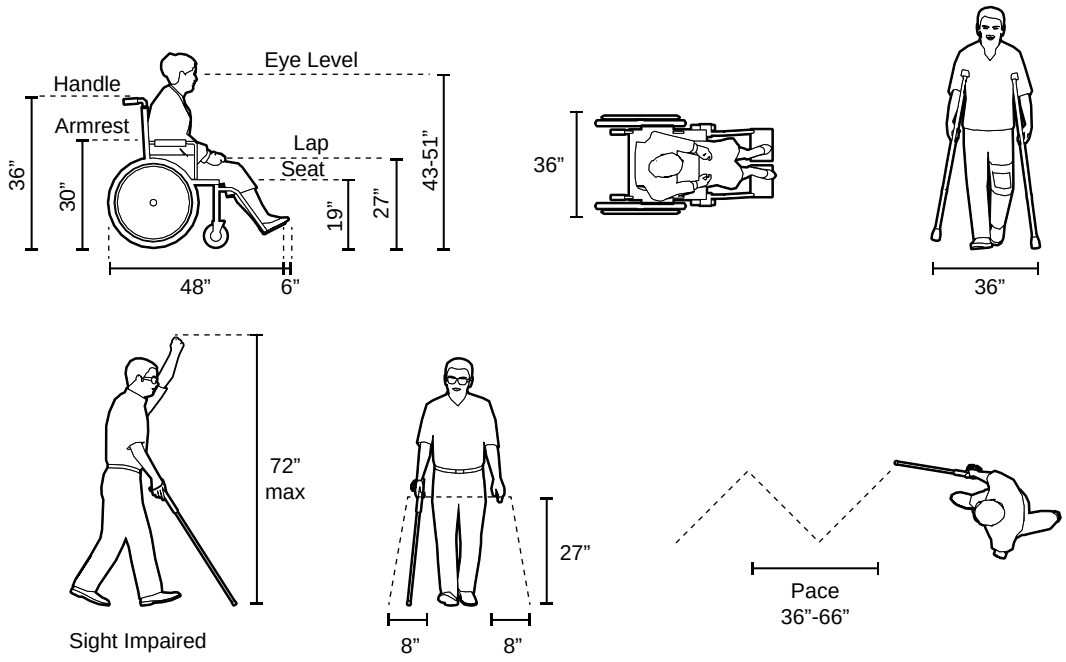
The lateral operating space extends beyond the physical space to allow pedestrians and bicyclists the natural side-to-side movement that varies with speed, topography, traffic conditions, wind, and proficiency.

The operating space of a person walking varies based on the purpose of the trip and the space available in front of them. In general, it is assumed that a person in a wheelchair or using crutches can operate within a width of 3 ft.

For pedestrians with mobility devices, spatial needs will vary. Figure 3-13[8] below illustrates the increased space that may be required to accommodate the movements of pedestrians with mobility devices.

To accommodate the side-to-side movement of almost all bicyclists, the minimum effective operating space clear of all obstructions for a bicyclist should therefore be 3.5 ft., which accounts for a 30 inch physical width and 6 inches of space on either side (see Figure 3-14). This operating space should provide a smooth, rideable surface clear of surface defects, joints, and other potential obstructions. Where it is desired to accommodate larger bicycles or larger variations in straight-line

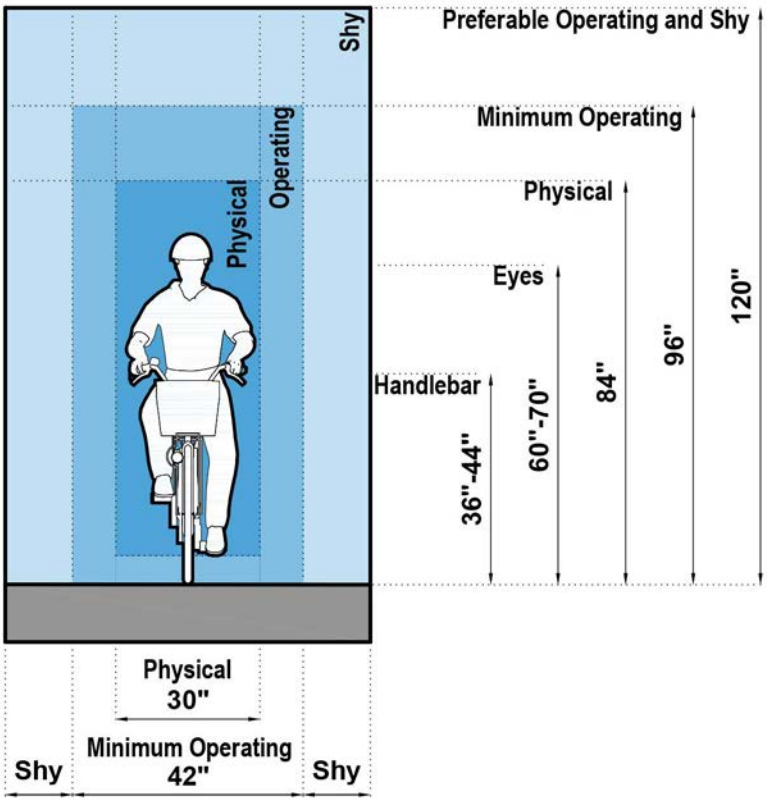
Figure 3-13: Spatial Dimensions for People Using Typical Mobility Devices



travel, the operating width should be increased. Additional discussion of conditions where shy space should be considered is provided in Section 3.6.2.

The operating space must also consider vertical clearances to obstructions such as trees, signs, utilities, ceilings and other potential hazards. Fixed objects should not be permitted to protrude within the vertical operating space of a bicycle or pedestrian facility. The recommended minimum vertical operating space that may be used is 8 ft. The preferable vertical operating and shy space is 10 ft.

Figure 3-14: Typical Adult Bicyclist Operating Space



3.6.2. Shy Spaces

To maintain comfort and safety of pedestrians and bicyclists, it is important to consider providing clearances to obstructions adjacent to sidewalks and bikeways. For example, a contributing factor in many bicycle crashes is a bicyclist striking another person or object with their handlebar or wheel. Clearances to vertical elements should be provided as shy spaces located outside the operating space of the bicyclist. However, for bikeways within the roadway, it may not always be practicable to provide shy space to parked and moving motor vehicles just as sidewalks are sometimes placed directly adjacent to the curb and moving vehicles. Where minimum shy spaces are not provided, the useable width intended for bicycle travel and pedestrian movement, and the level of comfort for the facility, is likely to be reduced.

This section provides guidance for determining an appropriate clearance distance to obstructions and on the relevance of shy space for common contexts. See Table 3-13 for bicyclist shy spaces to common vertical elements.

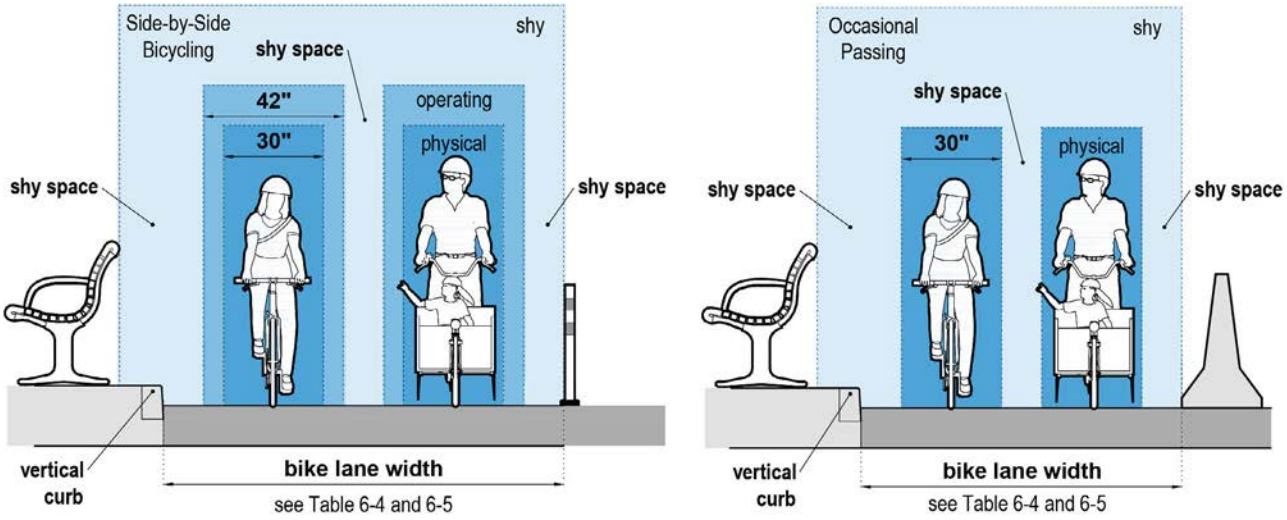
Table 3-13: Bicyclist Shy Spaces

Vertical Element	Shy Space (in.)	
	Minimum	Constrained
Bicycle Traffic	12	6
Intermittent (tree, flex post, pole, etc.)	12	0
Continuous (fence, railing, planter etc.)	24	12
Vertical Curb	12	6
Mountable / Sloping Curb	0	0

Bicycle Traffic

People walking or bicycling have the potential to collide into other bicyclists or pedestrians (on shared use paths) where a facility width limits a users' ability to operate side-by-side, to pass other users of the same mode, or to pass other modes. Sidewalks and bikeways should be constructed to serve the expected volume of users to minimize this crash risk. A minimum shy space of 12 inches should be included to accommodate passing or side-by-side bicycling, though this may be reduced to 6 inches in constrained conditions. Where it is desired to accommodate side-by-side bicycling or frequent passing, shy space should be provided between the operating spaces of each user. Where it is not desired to encourage side-by-side bicycling, shy space should still be provided between the physical spaces of each bicyclist to accommodate occasional passing. Figure 3-15 depicts shy space from both physical and operating spaces for side-by-side bicycling and occasional passing scenarios.

Figure 3-15: Bicyclist Shy Space to Vertical Elements Accommodating Side-By-Side Bicycling and Occasional Passing



Intermittent Vertical Elements

Intermittent vertical elements along the edge of a bicyclists' path, such as trees, signs, utility poles, flexible delineator posts, or other similar objects, can increase the risk of handlebar strikes or bicycle trailers striking vertical elements. Similarly, pedestrians will position themselves away from these obstructions to avoid hitting them with their arm or belongings. Where these features are present, the minimum shy space is 1ft., although the shy space may be eliminated in constrained areas. Exceptions to this guidance are as follows:

- The OMUTCD requires no portion of a sign or its support to be placed less than 2 ft. laterally from the near edge of a shared use path. Where space is available, wider shy spaces are desirable.
- Bicycle-only pushbuttons or pushbuttons on shared use paths should be located close enough to be pressed without dismounting and placed based on pedestrian accessibility guidelines. The OMUTCD and Chapter 8 provide additional guidance on the location of pushbuttons.
- Lean rails and footrests intended for the use of bicyclists at intersections are an exception to the shy distance guidelines and should be located close enough to be functional from the bikeway. Bikeways may be widened to provide shy distances and allow these treatments to be functional.

Continuous Vertical Elements

Continuous vertical elements, such as fences, railings, barriers, and walls, can also increase the risk of handlebar and bicycle trailer strikes. In this case, the constant presence of these elements will result in pedestrians and bicyclists attempting to increase their separation from them as these elements create a feeling of enclosure. Where these features are present, a minimum buffer width is 2 ft., but may be reduced to 1 ft. in constrained locations. Where space is available, wider buffers are desirable. Designers may use warning signs, object markers, or enhanced conspicuity and reflectorizing of the obstruction to draw attention to their presence.

Curb and Gutter

Some curb types can increase the risk of bicycle crashes if struck by a wheel or pedal. The face of curb angle—vertical, sloping, and mountable—and curb height influence the functional width of the bikeway, crash risk to bicyclists, the ability to exit bikeways, and the risk of encroachment into the bikeway by other users. In locations where the bikeway is located between curb on one or both sides, it is preferable to provide sloping curbs or reduced height vertical curbs (less than 3 inches). The following shy distances should be used for the different curb types:

- Where vertical curbs are provided, the minimum shy space is 6 inches and the preferable shy space is 1 ft.
- Where sloping curbs are provided, there is no minimum shy space adjacent to the curb; however, shy space behind the curb to other appurtenances is still relevant.
- Where mountable curbs are provided, there is no minimum shy space adjacent to the curb; however, shy space to other appurtenances should be carefully considered along the bicyclists expected path of travel if they are permitted to exit the bikeway (such as to access bicycle parking).
- Where curb with integral gutter creates a longitudinal joint parallel to the bikeway, the gutter area is not included in the width of the bikeway but there is no minimum shy space from the edge of gutter.

Some curbs are constructed with integral gutters that include a longitudinal seam parallel to bicycle travel that may deteriorate, resulting in dips or ridges that increase crash risk for bicyclists. Gutters also may have uneven surfaces where street resurfacing activities do not adequately remove asphalt approaching the gutter. Where curbs are provided with integral gutter, the minimum shy space from the bicyclist to the curb is the width of the gutter. See Chapters 4 and 6 for additional information relating to curb selection and design.

Some curb heights may warrant a railing when introduced within a walking area that is separating a lower portion of sidewalk from an upper portion of sidewalk. A railing should be installed when that curb height is greater than 6 inches and consideration should be given to including one when the curb height is at 6 inches. The railing serves as protection and support for pedestrians with vision impairments.

Vertical Clearance

The preferred vertical clearance to overhead obstructions is a minimum of 10 ft. for sidewalks, shared use paths, and bikeways. If any portion of a pedestrian facility has a clearance less than 80 inches., it shall be shielded by a barrier which is detectable with a cane at an elevation no higher than 27 inches.[9] The minimum vertical clearance that may be used in constrained areas is 8 ft. In some situations, vertical clearance greater than 10 ft. may be needed to permit passage of maintenance and emergency vehicles or where equestrian use may be expected. Providing additional vertical clearances can also improve the comfort of a facility in an otherwise constrained location (e.g., a relatively long underpass). Vertical clearance should be considered for underpasses and tunnels, as well as for overhead signs, trees, and other appurtenances that may extend over a bicycle or pedestrian facility.

3.6.3. Horizontal Alignment

Basic horizontal geometric design guidelines for motor vehicles will typically result in a facility that accommodates bicyclist and pedestrians. Guidelines for the horizontal alignment of shared use paths that deviate from a roadway alignment will be discussed in more detail in Chapter 5 as a part of the shared use path design principles.

Sidewalks

While the horizontal alignment for sidewalks typically follows the roadway, designers may have a situation where the sidewalk is independent of a roadway and in these situations, care should be given to providing consistent design elements. For pedestrians with vision impairments or using mobility devices, sidewalks with straight alignments are preferred for ease of navigation. If any curvature is introduced, it should be gradual and sweeping, with forgiving infrastructure adjacent to the walk, preventing pedestrians with vision impairments from wandering off of the sidewalk because the edge is difficult to detect, and minimize maneuvers for pedestrians with mobility devices.

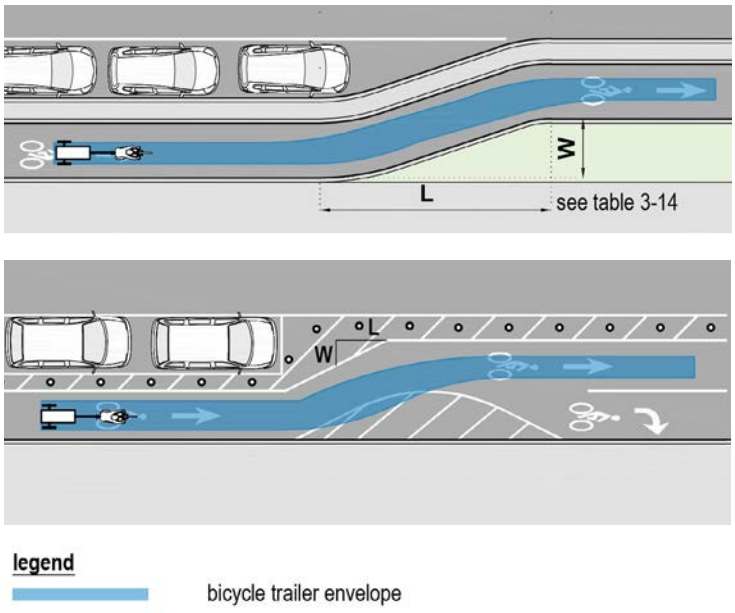
Bicycle Tapers

Changing the horizontal alignment of a bikeway may be accomplished without the use of horizontal curves if shifting tapers are used. Tapers should generally occur gradually, with a minimum length as calculated using the formula in Table 3-14. If the bikeway is delineated by paint-only, and if the off-tracking of a bicycle pulling a trailer would not put the trailer into a motor vehicle lane, a maximum taper ratio of 2:1 (longitudinal:lateral) may be considered. See Figure 3-16.

Table 3-14: Shifting Taper Equation

Lane Shift Taper Equation		
$L = \frac{WS^2}{60}$		
Where:		
L	=	lane shift (ft), minimum 20 ft
W	=	width of offset (ft)
S	=	target motor vehicle operating speed (mph)

Figure 3-16: Bikeway Shifting Tapers



3.6.4. Cross Slope

For all facilities that include pedestrians, cross slope design should meet pedestrian accessibility guidelines and should be 1.56 percent to comply with ADA Standards. Cross slopes of 1 percent are more comfortable for people with disabilities and people bicycling with more than two wheels (e.g., cargo bike, adult tricycles, or trailers). In cases where the facility is designed for bicycle use only (e.g., pedestrians are accommodated on a separate walkway), cross slopes may exceed pedestrian accessibility guidelines.

3.6.5. Vertical Alignment

For facilities shared by bicyclists and pedestrians and for pedestrian only facilities, longitudinal grades should meet pedestrian accessibility guidelines. A sidewalk or bikeway adjacent and parallel to a roadway should generally match the grade of the adjacent roadway. Where a bikeway runs parallel to a roadway with a grade that exceeds 5 percent, the bikeway grade may exceed 5 percent but should be less than or equal to the roadway grade.

3.7 Other Considerations

3.7.1. Utilities

It is common to locate utilities within roadway corridors and to take advantage of utility rights-of-way to construct trails and shared use paths. This often creates challenges related to placement of utilities in relation to bicycle facilities.

Addressing utility location may not be practical in retrofit situations where minimal reconstruction is anticipated. However, new construction or substantial reconstruction presents opportunities to proactively address utility placement. Careful consideration of utilities within a roadway corridor can minimize potential utility conflicts and ensure adequate maintenance access for both utilities and bicycle facilities. Utility placement should be coordinated early in the project with utility owners and as part of the drainage and signal design. The following list represents common utility issues that may be encountered when designing bicycle facilities.

Adjacent Utility Features

The usable width of bikeways and sidewalks is reduced if a utility feature such as a pole or fire hydrant is located immediately adjacent to a bikeway. See Section 3.6.2 for information on shy distances to obstructions. It is preferable to locate fire hydrants in the buffer adjacent to a sidewalk or bikeway. Designers should coordinate with the local water department to determine exact hydrant placement. Additionally, the placement of valves, pull boxes, manhole lids, and grates could impact the design of curb ramps at pedestrian crossing locations.

Guy wires for overhead pole lines can create a vertical obstruction for pedestrians and bicyclists. The angle of the guy wire within the bicycle and pedestrian facility will require analysis to ensure the wire doesn't extend into the vertical clear zone and create the risk of a pedestrian or bicyclists running into the wire.

Pad mounted transformers, telecommunication cabinets, and other cabinets for surface utilities can cause obstructions in the pedestrian access route or bicycle path. When designing pedestrian and bicycle facilities, coordinate existing infrastructure with the utility owner and facility design to provide the minimum accessibility width. If relocating these facilities, it is recommended these facilities be placed behind the sidewalk or bikeway as right-of-way permits to avoid vertical obstructions that could cause potential sight distance issues for the bicyclists or pedestrian and motorists.

Underground Utilities

Avoid locating utility covers and large ventilation grates within bikeways to maintain a level bicycling surface and minimize detours during utility work. Where unavoidable, utility covers and large ventilation grates within bikeways should be smooth and flush with the bikeway surface and placed in a manner that minimizes the need for avoidance maneuvers by bicyclists. In addition, keeping manholes flush within one-quarter inch below the pavement surface helps to avoid impacts to winter maintenance equipment. When utility cuts are necessary within a bikeway, the repaired pavement should extend the entire width of the bike lane to prevent uneven riding surfaces.

Due to their typically large size, ventilation grates may present a skidding hazard if located in a bikeway. If placement in a bikeway is unavoidable, designers should consider skid resistant treatments.

For pedestrian facilities, utility covers and grates must meet gap requirements for openings and surface treatment requirements for accessibility guidelines, i.e., ¼-inch maximum. If these elements are not accessible, the grate or cover can impact the accessible width of the pedestrian facility.

Traffic Signal Equipment

The addition of bikeways within the footprint of an existing roadway often results in the need to realign traffic signal heads and detection equipment. Designers should consider configuration of traffic signal and detection equipment in relationship to alignment of travel lanes to determine whether traffic signal modifications are necessary. Additionally, the placement of signal cabinets should be considered when assessing sight lines to ensure that the equipment will not result in sight obstructions. See Chapter 8 for a discussion of bicycle signals and placement of pushbuttons.

Some pedestrian signal equipment is required to meet ADA requirements and is discussed in Chapter 4. Other pedestrian signal elements can include rapid rectangular flashing beacons and pedestrian hybrid beacons. For design information related to these elements, see Chapter 8, OMUTCD Parts 4 and 9, and TEM Parts 4 and 9.

3.7.2. Lighting

A properly lit area creates a comfortable and functional environment for all street users. A well-lit street provides drivers with more opportunity to see the bicyclists or pedestrians in the roadway and to stop or maneuver to avoid them. For both pedestrians and bicyclists, lighting directly impacts real and perceived safety, influencing one's decision and willingness to walk or bike in an area.

For sidewalks, bikeways, and shared use paths, fixed-source lighting improves visibility along the path of travel, allowing users to better detect surface irregularities at night. Provision of lighting appropriate for all users should be considered, especially when night-time use is anticipated, such as the following locations:

- On pedestrian and bicycle facilities that provide connections to transit stops and stations, schools, universities, shopping, and employment areas,
- Under vehicular bridges, underpasses, tunnels, or locations with limited visibility,
- Along bridges used by bicycles and pedestrians,
- Along high-use portions of facilities that lead to areas with frequent evening events,
- At intersections or driveways where crossing are required, and
- At major shared use path intersections and entrances.

Along pedestrian and bicycle facilities, pedestrian-scale lighting is preferred to tall, highway-style lamps. Pedestrian-scale lighting is characterized by shorter light poles (approx. 15 ft. high), lower levels of illumination (except at crossings), closer spacing (to avoid dark zones between luminaires), and high-pressure sodium vapor, metal halide, or light emitting diode (LED) lamps. This approach to lighting design can improve lighting uniformity along the walkway or bikeway and at conflict points, helping to address issues of social safety and bicycle and pedestrian visibility. Streetlights should comply with local streetscape or historic district guidelines to enhance placemaking and work in the local context.

Depending on the location, average maintained horizontal illumination levels of 0.5- to 2-ft candles should be considered, and lighting levels should provide a uniform illumination of the walkway and bikeway surface. Higher lighting levels may be appropriate in some locations to increase the perception of personal safety.

Placement of light poles should provide the recommended horizontal and vertical clearances from the walkway and bikeway. Where pedestrians cross bikeways, or where bicyclists or pedestrians cross motor vehicle paths, the lighting placements should front light (illuminate) the crossing user to make them more visible to the approaching bicyclist or motorist.

Light fixtures should be chosen to reduce the loss of light and may need to comply with local “dark sky” guidelines and regulations. Lighting in natural and undeveloped areas may ultimately be undesirable to mitigate environmental disturbance, or may be designed to dim or turn off lighting after curfew along riparian corridors and other less/undeveloped areas.

Additional guidance for lighting can be found in the AASHTO *Roadway Lighting Design Guide and the TEM Section 1100.*

3.7.3. Drainage

Drainage should be considered when designing bike and pedestrian facilities to prevent water ponding, ice formation, and the collection of debris. Proper drainage protects the longevity of the infrastructure, reduces erosion, and follows local and state guidance for stormwater runoff

collection. The minimum recommended hard surface cross slope of 1 percent typically provides adequate conveyance of drainage. For sidewalks or bikeways, sloping in one direction instead of crowning is preferred and simplifies drainage and surface construction.

Bikeways along or within a road corridor typically follow the slope and drainage patterns of the respective roadway, and may be incorporated into the roadway's drainage system. If the bikeway changes drainage patterns or adds impervious area to the design, the roadway's drainage system will likely need to be modified or expanded.

Utility covers and bicycle compatible grates should be flush with the surface of the pavement on all sides. Any horizontal openings shall not permit passage of a sphere more than 0.5 inches in diameter. Any elongated openings shall be placed so that the long dimension is perpendicular to the direction of travel.

Pedestrian accessibility guidelines also limit vertical deviations in surfaces of more than 0.25 inches. To minimize risks to pedestrians, drainage grates, utility covers, and gutters should not be located within bicycle facilities where pedestrians are traveling unless they meet pedestrian accessibility guidelines.

Any infrastructure located in low-lying areas may need special attention to larger scale drainage and flooding issues. Designers may need to capture excess stormwater to prevent standing water or erosion on a pedestrian or bicycle facility.

For pedestrian facilities, positive drainage at the base of curb ramps is critical to prevent debris from gathering or water from ponding during rain events or freezing in cold weather. Placing a catch basin or inlet immediately upstream from a curb ramp will capture a majority of storm runoff prior to the water passing the curb ramp base, minimizing the amount of water flowing past the ramp area. Minimum sidewalk cross slopes should be maintained to promote positive drainage away from the sidewalk area. Ideally, where curb or curb and gutter exist, sidewalks will slope to the roadway, directing water over the curb to the gutter and into a storm sewer system. Where a swale is placed between the roadway and the sidewalk, or at the back of sidewalk and water is directed into the swale, the swale design shall follow L&D Manual Volume 2 and ensure adequate freeboard is provided to prevent water from overtopping the swale and ponding on the sidewalk.

3.7.4. Landscaping

Landscaping should follow the guidance in L&D Manual Volume 1, Sections 600 and 900. Landscaping must be designed to allow sufficient sight distance, and proper offsets should also be provided from roadways to comply with clear zone and urban arterial offsets.

Well-designed landscaping—trees, shrubs and grasses—alongside sidewalks and bike facilities creates a more pleasant walking and bicycling environment, improves community aesthetics, and can help to reduce motorist speeds by visually narrowing the roadway. Landscaping, including defining maintenance roles, should be coordinated during preliminary design stages.

Street trees are the primary consideration for landscape design along sidewalks and separated bike lanes. With respect to the separated bike lane cross-section, trees may be located in the street buffer, in sidewalk buffers, or both. The street buffer is the recommended tree planting location to preserve usable sidewalk width and enhance the separation between motor vehicles and bicyclists in constrained corridors, but the sidewalk buffer may be considered to provide shade for the sidewalk or where the street buffer is too narrow.

When selecting tree species, ensure compatibility with the bicyclist operating height (100 inches vertical clearance from bike lane surface to tree branches). Avoid shallow rooted species and species that produce an abundance of fruits, nuts, and leaf litter. Properly designed tree trenches, tree pits, or raised tree beds can support root growth to preserve pavement quality of the adjacent separated bike lane. Coordinate street tree species selection with overhead utility owners to identify a tree that will not require extensive trimming to avoid interference with the utility lines as it matures. This will preserve the future tree canopy, increasing the shade and aesthetics of the bicycle and pedestrian facilities.

Where on-street parking is present, intermittent curb extensions with street trees between parking spaces can preserve sidewalk space and visually narrow the roadway for a traffic calming effect.

Tree plantings can also be integrated with stormwater management techniques, including permeable surface treatments.

The design of separated bike lanes and side paths in rural and low-density suburban communities should follow natural roadside design considerations. Natural roadside corridors are bound by the limits of the available right-of-way and should be designed accordingly. Motor vehicle speeds in these corridors are typically higher than in urban environments, therefore it is important to maximize the street buffer to the extent possible to provide greater separation from high-speed motor vehicle traffic. Methods to achieve this may include:

- fitting the separated bike lane or shared use path to the natural terrain, but maintaining grades that are comfortable for bicycling and meet ADA requirements if pedestrians are present;
- avoiding and minimizing impacts to wetland resources or other natural environments;
- where possible, maintaining natural drainage patterns and minimizing erosion through the use of vegetated drainage channels in the street buffer; or
- maintaining access for periodic mowing and other maintenance activities.

3.7.5. Surface Conditions

It is important to construct and maintain a smooth traversable surface on pedestrian and bicycle transportation facilities. Wheelchairs, electric mobility scooters, bicycles, and other wheeled users require firm, stable surfaces and structures (eg. ramps, beveled edges) since they can be difficult to propel over uneven surfaces. Hard, all-weather pavement surfaces are recommended for pedestrian and bicycle facilities. For on-street and separated bike lanes, concrete or asphalt pavement is typically appropriate.

Shared use paths must meet pedestrian accessibility surface requirements. All-weather pavement is preferred compared with crushed aggregate, sand, clay, or stabilized earth. Since unpaved surfaces provide less traction, they decrease braking ability for bicyclists which can cause bicyclists to more easily lose control. On unpaved surfaces, bicyclists and other wheeled users must use a greater effort to travel at a given speed when compared to a paved surface. Some path users, such as skaters, are unable to use unpaved paths. In areas that experience frequent or even occasional flooding or drainage problems, or in areas of moderate or steep terrain, unpaved surfaces will often erode and require substantial maintenance. Additionally, unpaved paths are difficult to plow for use during the winter.

On shared use paths, loads should be substantially less than roadways. However, paths should be designed to sustain wheel loads of occasional emergency, patrol, maintenance, and other motor vehicles that are permitted to use or cross the path. When motor vehicles are driven on shared use paths, their wheels often will be at, or very near, the edges of the path. This can cause edge damage that, in turn, will reduce the effective operating width of the path. The path should, therefore, be constructed of sufficient width to accommodate the vehicles, and adequate edge support should be provided. Edge support can be provided by means of stabilized shoulders, flush or raised concrete curbing, or additional pavement width or thickness. The use of flush concrete curbing has other long-term maintenance benefits, such as reducing the potential for encroachment of vegetation onto the path surface. If raised curbs are used, refer to Section 3.6.2 for shy distance and curb design considerations.

Rumble strips and stripes are tactile patterns constructed along the edge of a travel lane or paved shoulder or along the road center line. They are typically milled into existing pavement, but sometimes they are created by adhering raised devices to the pavement.[10] The texture of rumble strips is different from that of the roadway surface, and is designed to give motorists an audible and tactile cue to correct their course when a motorist drives over them. Longitudinal rumble strips and stripes that are milled into the roadway surface have proven to be an effective and inexpensive way to reduce run-off-road crashes for motorists on high-speed roadways.[11] However, they can be difficult for bicyclists to traverse and can render popular and useful bicycle routes or shoulders unusable by bicyclists. The effect of some rumble strip designs on bicyclists can be significant if not properly mitigated, causing the bicycle to shudder violently and/or the bicyclist to lose control. Additional details on the design and placement of rumble strips and stripes is discussed in Chapter 6.

Railroad tracks that interface with pedestrian and bicycle facilities can be hazardous to wheelchair users, mobility impaired, and bicyclists. See Chapter 11 for railroad crossing considerations.

Chapter 3 Endnotes

1 FHWA. Bicycle and Pedestrian Facility Design Flexibility. Memorandum. HEPH-10. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2013.

2 Jacobsen, P. L. Safety in Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling. *Injury Prevention*, Vol. 9, No. 3, 2003, pp. 205–209.

3 Elvik, R. The Non-Linearity of Risk and the Promotion of Environmentally Sustainable Transport. *Accident Analysis and Prevention*, Vol., 41, No. 4, 2009, pp. 849–855.

4 Marques, R. and V. Hernandez-Herrador. On the Effect of Networks of Cycle-Tracks on the Risk of Cycling: The Case of Seville. *Accident Analysis and Prevention,* Vol. 102, 2017, pp. 181-190.

5 http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/net work_report/network_report.pdf

6 Dill, D. and N. McNeil. Revisiting the Four Types of Cyclists. In *Transportation Research Record 2587.* TRB, National Research Council, Washington, DC, 2016.

7 https://www.fhwa.dot.gov/publications/research/safety/pedbike/05085/chapt8.cfm

8 https://www.fhwa.dot.gov/publications/research/safety/pedbike/05085/pdf/lesson8lo.pdf

9 U.S. Access Board. Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way. 36 CFR, Part 1190, 76 Federal Register 44664, published July 26, 2011. United States Access Board, Washington, DC, 2011. http://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines.

10 AASHTO. *A Policy on Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, Washington, DC, 2011.

11 Torbic, D. J., J. M. Hutton, C. D. Bokenkroger, K. M. Bauer, D. W. Harwood, D. K. Gilmore, S. M. Dunn, J. J. Ronchetto, E. T. Donnell, H. J. Sommer III, P. Garvey, B. Persaud, and C. Lyon. *National Cooperative Highway*

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CHAPTER 4: PEDESTRIAN FACILITIES

Chapter 4: Pedestrian Facilities

4.1 Introduction

This chapter expands on the guidance provided in Chapter 3, focusing on specific factors that influence the design of pedestrian facilities. Pedestrian facility design decisions should be informed by the context of the complete roadway environment, including the adjacent and nearby land uses and traffic operations. The quality of the pedestrian environment is impacted by a number of factors, including traffic volumes and speeds, sidewalk widths, sidewalk buffer widths, block lengths, landscaping, lighting, and the design of street crossings, among others. The biggest determinants of pedestrian safety are a person's proximity and exposure to motor vehicles while walking along streets and crossing streets.

4.2 Disabilities and Accessibility

A disability is the result of a medically defined condition that limits a person's movement, sense, or activities. Disabilities can be permanent or temporary and can affect anyone at some time in their life. Disability types include:

- Physical (Orthopedic)
- Physical (Medical)
- Vision
- Hearing
- Cognitive/Neurological

Orthopedic physical disabilities often require the use of a mobility device, including a cane, walker, wheelchair or prosthetic. Medical physical disabilities affect a person's body, such as the lungs or heart, and can limit physical exertion. Vision and hearing disabilities include both full loss of either sense as well as low levels of function for those senses. Cognitive and neurological disabilities can include effects of brain injuries, autism or other impairments that can decrease decision making and recognition abilities.

Individuals with disabilities may experience accessibility issues when faced with:

- Curbs located along the edge of a roadway, at a driveway, on a median island, at roundabouts, or anywhere that the straight vertical face prohibits pedestrians from moving without requiring a step up, down, or over the curb
- Vertical discontinuities
- Route widths that prohibit movement through a corridor
- Steep grades or cross slopes that require extra exertion to overcome or that can cause instability
- Obstructions within the pathway that may go undetected and be struck by the individual

- Excessive reach distances to pushbuttons
- Accessible facilities that are blocked by other infrastructure and prohibit access
- Rough surfaces that cause jarring of the individual or impede manuverability over the surface
- Striping that is not high contrast
- Horizontal gaps in infrastructure that can cause tripping or catch mobility devices
- Roadway crossings

Under the Americans with Disabilities Act, all programs and new and altered facilities, regardless of funding, must be designed to remove these barriers, create consistency in the accessible features, and ensure access for all users. Accessible designs are required for the following:

- Sidewalks
- Pedestrian over- and underpasses
- Pedestrian circulation paths (including temporary paths provided during construction or closure activities)
- Pedestrian street crossings including medians or crossing islands, roundabouts, and channelized turn lanes
- Signalized intersections
- Curb ramps
- Pedestrian signals and pushbuttons
- On-Street parking that is marked or metered
- Passenger loading zones
- Transit stops
- Pedestrian at-grade rail crossings
- Pedestrian signage
- Street furniture
- Ramps, stairways, or other facilities to access buildings that fall within the public right-of-way

ODOT has identified the *2011 Proposed Accessibility Guidelines for Pedestrian Facilities in Public Rights-of-Way* (PROWAG) as the current governing design document for accessible features on transportation projects. With this identification, the requirements found within the 2011 PROWAG, except for R306.3.2 Pedestrian Activated Signals, are mandatory and must be complied with on ODOT-Let and Local-Let projects. This chapter provides guidance on accessible design criteria as defined by ADAAG, PROWAG, and ODOT requirements. ODOT is awaiting final guidance on pedestrian accessibility requirements at multilane roundabouts from the U.S. Access Board. For ODOT's current roundabout guidance, see Section 9.4.4.

To satisfy the requirements of the ADA, transportation projects must provide accessible designs as outlined in this chapter. Deviations from accessible design standards should be justified and documented (see Section 4.5.9.7).

4.3 Pedestrian Zone Design

4.3.1. Types of Pedestrian Facilities

A variety of facilities can accommodate pedestrians. The design of each facility is dependent on the adjacent land uses and overall project context. This section provides an overview of these facilities with guidance for each provided throughout this chapter.

4.3.1.1 Walkways and Sidewalks

Sidewalks and paved or improved walkways are the primary facility for accommodating pedestrians. A sidewalk is a walkway that is located along a roadway. A walkway may follow the roadway alignment, or it may be located on an independent alignment that is for use by pedestrians.

4.3.1.2 Shared Use Paths and Side Paths

Shared use paths and side paths are walkways that are also used by bicyclists. They are discussed in more detail in Chapter 5.

4.3.1.3 Roadway Shoulders

Wherever pedestrians are expected, pedestrian facilities should be provided. ORC Section 4511.50 states:

(A) Where a sidewalk is provided and its use is practicable, it shall be unlawful for any pedestrian to walk along and upon an adjacent roadway.

(B) Where a sidewalk is not available, any pedestrian walking along and upon a highway shall walk only on a shoulder, as far as practicable from the edge of the roadway.

(C) Where neither a sidewalk nor a shoulder is available, any pedestrian walking along and upon a highway shall walk as near as practicable to an outside edge of the roadway, and, if on a two-way roadway, shall walk only on the left side of the roadway.

The preferred facility for pedestrian travel along a road is a sidewalk. Shoulders are not a substitute for well-designed pedestrian facilities, however when pedestrians are expected and the roadside space is constrained, it is preferable to accommodate pedestrians by providing a wide shoulder to reduce pedestrians walking within the roadway. The use of a shoulder as a pedestrian facility will be determined on a case-by-case basis and approved by the ODOT Office of Roadway Engineering. In some situations, such as accessing transit stops or key community resources, the provision of accessible slopes, accessible widths, and detectable warning surfaces within the shoulder may be appropriate.

Wide shoulders may also be used as an interim measure until sidewalks can be installed. For other techniques where sidewalks are not possible or for interim treatments, designers may reference the information on the design and implementation of pedestrian lanes in *FHWA's Rural Design Guidance.*

Shoulders intended to be used by pedestrians should be maintained in a manner that supports pedestrian use. This includes clearing the shoulder of debris and vegetation and maintaining the

surface condition. Special attention should be paid to drainage design and snow storage policy to maximize pedestrian safety and comfort.

4.3.1.4 Shared Streets

Shared streets shall be organized in a manner that facilitates navigation by pedestrians with vision disabilities. Accessibility requirements shall follow the requirements of sidewalks. Visual and tactile cues should be provided to identify the presence of a shared street and to delineate between pedestrian-only and shared zones, including from the crossing sidewalk. Surface treatments and materials can vary, but for the shared street to be accessible the surface must be firm and stable. While there are no specific design requirements besides adhering to the accessibility requirements for sidewalks, there are several resources available to support the design of accessible shared streets. The *FHWA Accessible Shared Streets Guide* and the *NACTO Urban Street Design Guide* both provide guidance on best practices for shared streets.

4.3.2. Pedestrian Zone Framework

The space between the curb, or edge of pavement on uncurbed roadways, and the property line plays an important role in:

- providing safe and efficient movement of pedestrians of all ages and abilities;
- access to properties, on-street parking, and transit;
- space for above ground street utilities, traffic control, street scaping, green infrastructure, and street furniture; and
- space for outdoor dining, street vendors, and other community life.

This space can include three zones: the pedestrian through zone, the frontage zone, and the buffer zone. Each performs unique functions in the overall operation of the street, and each interfaces with adjacent private property uses. Although boundaries between zones may blur and blend, the overall function of each zone generally remains consistent. Figure 4-1, Figure 4-2, and Figure 4-3 demonstrate the pedestrian zone for three different contexts.

Figure 4-1: Curbed Roadway

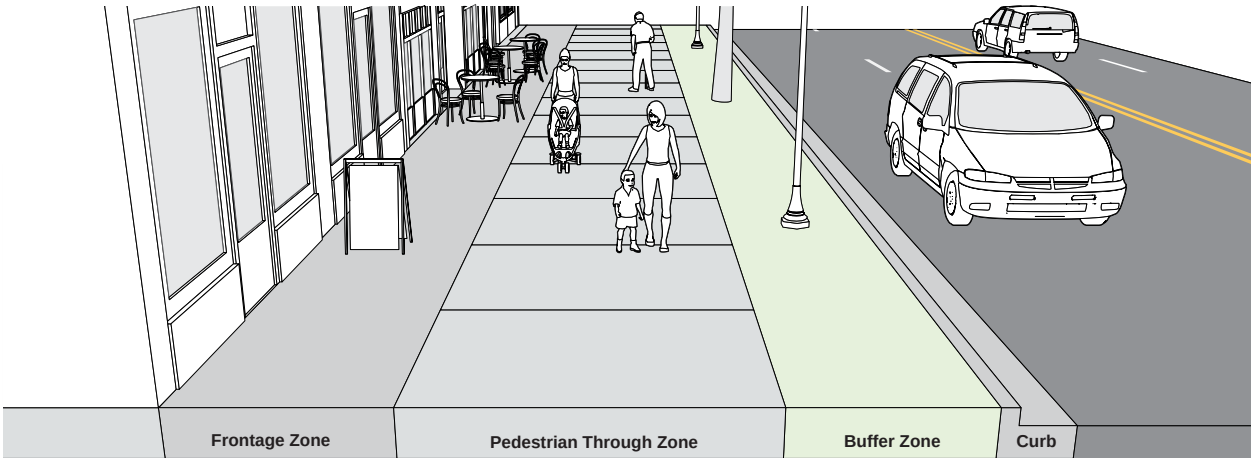


Figure 4-2: Uncurbed Roadway

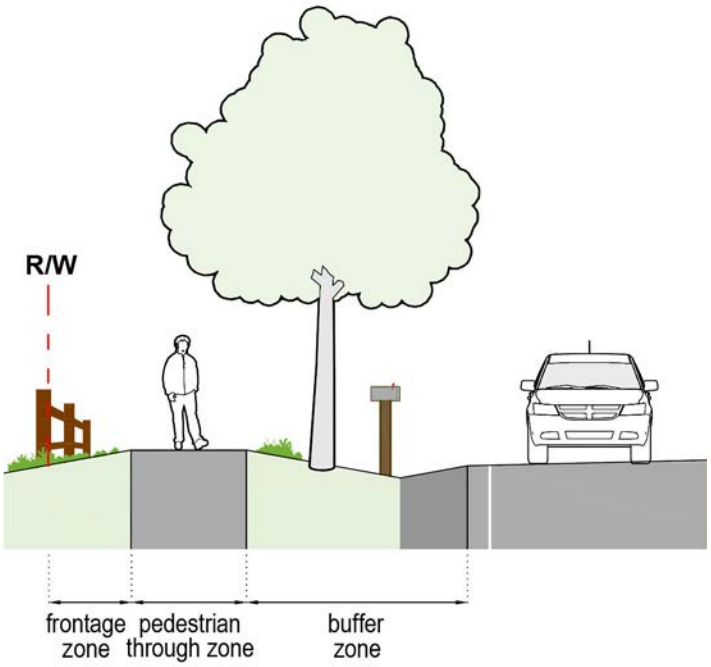


Figure 4-3: Uncurbed Roadway Where No Sidewalk Is Provided

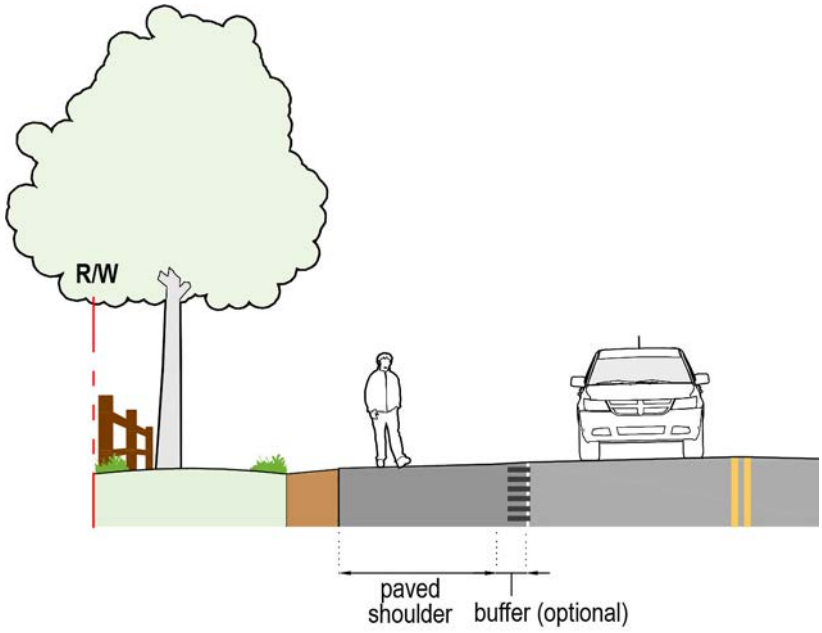


Table 4-1: Pedestrian Zone with Sidewalk Widths for Urban Core, Urban, Suburban, and Rural Town Areas

Land Use	Frontage Zone Minimum Width (FT)	Pedestrian Through Zone Sidewalk Width (FT) (B)	Buffer Zone Width (FT) (C)
Central Business District	2 – 6 (A)	8 - 14	4 – 8
Commercial	2 – 6 (A)	6 – 8	2 – 8 (D)
Residential	2	5 – 7	2 – 6 (D)

(A) 2 ft. Frontage Zone is the recommended minimum, and a 1 ft. Frontage Zone may be used in constrained environments. A 6 ft. Frontage Zone is the minimum width to accommodate sidewalk cafés.
(B) In rare, constrained conditions, the Pedestrian Through Zone width can be reduced to 4 ft, although this width does not provide adequate space for pedestrians passing in opposite directions and requires at least a 5 ft. wide by 5 ft. long passing sections every 200 ft. (see PROWAG Section R302.4).
(C) Where trees are desired and permitted within the buffer, the buffer width must sustain the long-term health and vitality of trees and accommodate the urban lateral offset or clear zone as appropriate.
(D) When a buffer cannot be provided, then the minimum curb- attached sidewalk width is 7 ft. for residential areas and 8 ft. for all other contexts. All roadways with curb-attached sidewalks or buffers should be constructed with vertical curbing.

Table 4-2: Pedestrian Zone with Shoulder Widths for Rural Areas

Roadway Characteristics	Pedestrian Through Zone Shoulder Width (FT)	Buffer Zone Width (FT)
Highway (ADT > 2,000 and less than 1 dwelling unit per acre)	See L&D Manual Volume 1, Figure 301-3 of (5 ft. minimum)	1.5 ft. to 4 ft.[1]
Highway (ADT < 2,000)	See AASHTO's *A Policy on Geometric Design of Highways and Streets* for combined traveled way and shoulder widths for local roads, collectors and Arterials	N/A

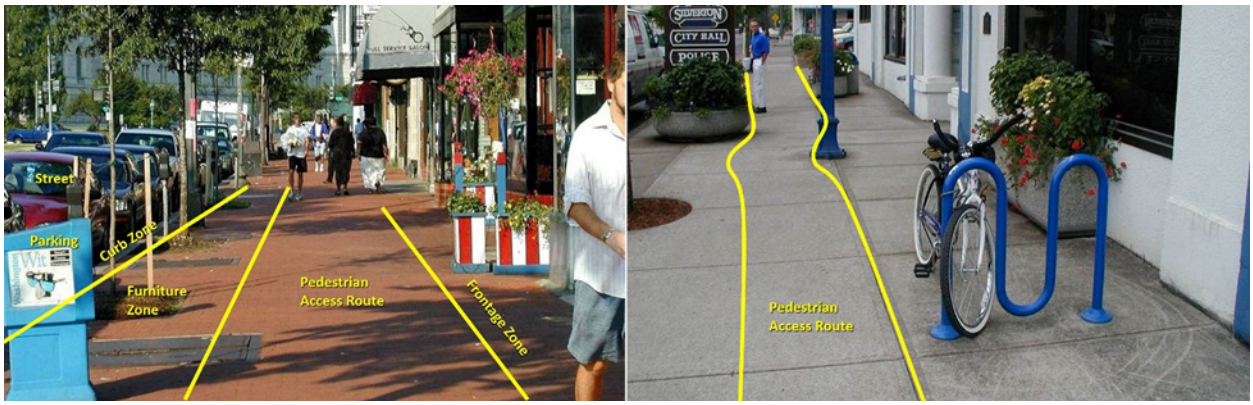
Pedestrian Through Zone

The Pedestrian Through Zone, also known as the "walking zone" or Pedestrian Access Route (PAR), is the portion of the sidewalk, shared use path, or shoulder used for pedestrian movement. For it to function, it must be kept clear of obstacles and be wide enough to comfortably accommodate expected pedestrian volumes, including those using mobility assistance devices, pushing strollers, or pulling carts.

Width: Refer to Table 4-1 and Table 4-2. In locations with very high pedestrian volumes, additional width should be considered.

Special Considerations: An accessible corridor is not necessarily an intuitive corridor. While sidewalks do not need to be perfectly straight, the Pedestrian Through Zone should not weave back and forth in the right-of-way. Figure 4-4 below illustrates two accessible corridors. For pedestrians with vision disabilities, a straight, wide corridor free from obstacles (as shown in the photo on the left) is easier to navigate than one requiring maneuvers or adjustments to the travel path to avoid obstacles (as illustrated in the photo on the right).

Figure 4-4: Photos showing an accessible and intuitive Pedestrian Through Zone versus a compliant but unintuitive Pedestrian Through Zone



Frontage Zone

The Frontage Zone is defined as the area between the back of the sidewalk and the property line which may coincide with the face of a building. In residential areas, the Frontage Zone may be occupied by front stairs, lawns, or other landscape elements that extend from the front door to the Pedestrian Through Zone edge. The Frontage Zone of commercial properties might include architectural features or projections, outdoor retailing displays, café seating, awnings, signage, and other intrusions into or use of the public right-of-way. Along some streets, the Frontage Zone is unimproved, but is present to accommodate sidewalk maintenance.

Width: Frontage Zone width will vary based on context, see Table 4-1. In general, a 2 ft. Frontage Zone is the recommended minimum, and a 1 ft. Frontage Zone is an acceptable minimum in constrained conditions. People walking tend to shy away from a building, wall, fence, steps or railing by at least 1 ft. Where buildings or other continuous objects are located against the back of the sidewalk and constrained situations do not provide width for the Frontage Zone, the effective width of the Pedestrian Through Zone is reduced by 1 ft.

Buffer Zone

The Buffer Zone, or "landscape zone," lies between the curb or edge of pavement and the Pedestrian Through Zone. In commercial areas, this zone may include hardscape pavement, pavers, or tree grates. In residential, or lower intensity areas, it is commonly a planted strip. The slope of the buffer zone varies, with 4-8 percent being typical. While the defined Buffer Zone lies behind the curb, on-street parking or bike lanes within the curb-to-curb width can also act as a sidewalk buffer by increasing the separation between the pedestrians and moving motor vehicle traffic. On curbed roadways where there is no on-street parking or bicycle lane, a sidewalk buffer is recommended.

When a roadway is uncurbed and surface runoff is collected in a roadside ditch or drainage swale, the swale may be between the Pedestrian Through Zone and traveled way as it eliminates the need for dedicated buffer space, limits the runoff and, reduces the chances of ice during winter months, and maximizes the space between pedestrians and motorized vehicles. However, the location of the drainage swale or ditch in relation to the Pedestrian Through Zone may vary depending on the context of the facility.

Width: Buffer Zone widths are described in Table 4-1 and Table 4-2[2]. When sidewalks are not present and pedestrians are using a roadway shoulder, a buffer may be inclusive of a rumble strip.

Special Considerations:

- The Buffer Zone can provide space for snow cleared from streets and sidewalks, although snow storage should not impede access to or use of important mobility fixtures such as parking meters, bus stops, and curb ramps.
- The Buffer Zone may extend into the parking lane by the use of curb extensions to provide additional space for trees, pedestrian ramps, bus shelters, bicycle parking, waiting areas, or other needs.

4.3.3. Walkway Surface Design

The accessible pedestrian facility design criteria are established by PROWAG and ODOT design requirements that meet the USDOJ and FHWA federal accessibility requirements. The design parameters in this chapter are intended to provide core criteria to be met on a project to satisfy federal accessibility requirements. There are several controlling criteria for a walkway to comply with the PROWAG and ODOT requirements for a pedestrian access route:

- Width
- Running Slope
- Cross Slope
- Surface Treatment
- Vertical Alignment/Vertical Surface Discontinuity
- Obstacles and Protruding Objects
- Horizontal Openings

Width

Refer to Section 4.3.2 for sidewalk width requirements and recommendations.

Running Slope

The running slope is measured longitudinally along a walkway. The following table summarizes the maximum criteria for ADA compliant running slopes.

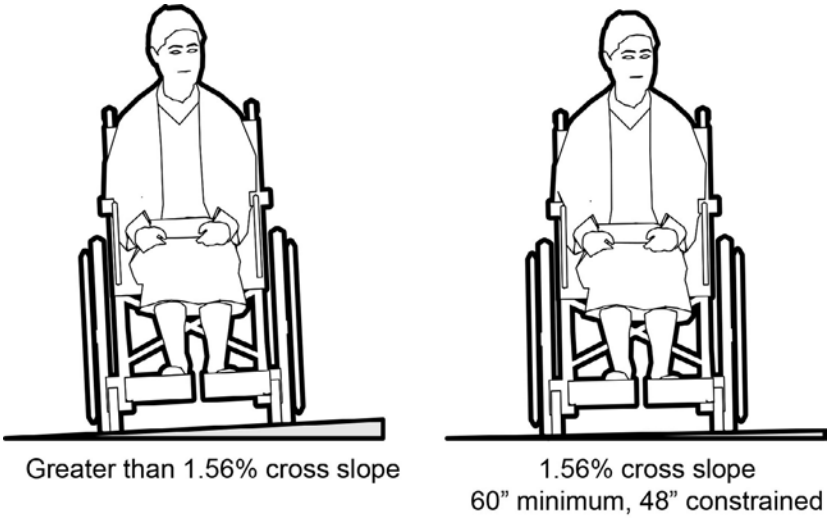
Table 4-3: Summary of ADA Compliant Running Slopes for Pedestrian Walkways

Walkway Location	Maximum Running Slope
Adjacent to Street	Matching grade of street
Separate Alignment	5 percent maximum without railing 7.69 percent maximum with railing
Within Street Crossing	5 percent maximum

Cross Slope

The cross slope of a pedestrian facility is measured perpendicular to the direction of pedestrian travel. Cross slopes can influence the stability and ease of maneuvering for pedestrians using a mobility device. When the cross slope is steep, pedestrians must shift their body weight and use more energy to maneuver through a corridor. Figure 4-5 illustrates the effect of sidewalk cross slope on a pedestrian using a wheelchair. As a pedestrian leans his or her body to compensate for a steep cross slope, the pedestrian's balance is impacted, causing instability and requiring more energy to make maneuvers, such as turning to align with a curb ramp.

Figure 4-5: Impacts of Sidewalk Cross Slope On Pedestrian Stability



Cross slope requirements apply to all sidewalks and walkways, street crossings, and at-grade railroad crossings, as well as pedestrian overpasses and underpasses and similar structures. The cross slope must meet or be less than the compliant cross slope for the entire width of the pedestrian access route. A driveway crossing should maintain a level pedestrian zone (see ODOT L&D Manual Volume 1, Figure 803-3, for sidewalk design at drives). Where pedestrian street crossings are without yield or stop control conditions (no yield or stop sign), or at a traffic signal that is designed for a green phase (no red phase) and vehicles do not slow to navigate the intersection, pedestrian street crossings have different cross slope maximums. The following table provides maximum cross slope information within the pedestrian access route.

Table 4-4: Summary of ADA Compliant Cross Slopes for Pedestrian Walkways

Walkway Location	Maximum Cross Slope
Within Street Crossing Without Yield or Stop Control at Intersection	5 percent
Mid-block Street Crossing	Match grade of street
All Other Pedestrian Walkways	1.56 percent

Surface Treatments

The sidewalk surface treatment affects the overall accessibility and comfort of the facility. The requirement is that the surface shall be a reduced vibration zone which is stable, firm, and slip resistant. Concrete and asphalt are the most commonly used surfaces, though other materials such as stone, brick, or pavers may be considered.

Concrete is the most commonly used sidewalk material. It provides a firm, smooth surface, with a color that contrasts from adjacent asphalt roadways, and its rigidity helps to maintain stable surface conditions over time. Asphalt can be used for sidewalks but is more commonly used for shared use paths. Although asphalt is firm and smooth, it does not provide a good contrasting color from asphalt roadways, and as a flexible pavement material it may adjust over time to slopes that no longer meet accessibility requirements. Where materials like bricks or pavers are used for aesthetic reasons, designers should design these treatments with a rigid base to avoid non-uniform settlement and surface irregularities that can be uncomfortable or inaccessible for wheelchair users or people pushing strollers. Bricks and pavers also tend to require more maintenance to maintain appropriate slopes and grades, which should be considered by the maintaining agency or property owner(s).

Vertical Alignment/Vertical Surface Discontinuity

The vertical alignment of the pedestrian access route shall be generally planar and smooth, promoting easy rollability. Materials that are textured, rough, or chamfered and cannot be placed in a manner that creates a planar and smooth surface should only be used for borders or used occasionally crossing the pedestrian access route.

Vertical surface discontinuities can prohibit movement between surfaces and create potential tripping hazards or areas where mobility devices can become stuck. Vertical surface discontinuities shall be 0.5 inches maximum, and any irregularity between 0.25 inches and 0.5 inches shall require a bevel with a slope no steeper than 50 percent applied across the entire surface of the irregularity. Objects such as utility covers, vault frames, and grates should not be located within curb ramp runs, blended transition turning spaces, or gutter areas within the pedestrian access route.

Obstacles and Protruding Objects

The Pedestrian Through Zones or walkways specified in Section 4.3.2 represent a clear or unobstructed pedestrian travel way. Designers should be aware of the three-dimensional corridor which makes up a pedestrian accessible route and place above-ground utilities, light poles, signs, fire hydrants, mailboxes, parking meters, street furniture, and other appurtenances outside of this sidewalk area. If unable to avoid keeping objects out of this space, then certain dimensional requirements must be maintained; see ADA *Standards R307 Protruding Objects* for requirements.

Directional indicators may also be used to aid pedestrians in taking the appropriate path through an area. Directional tactile indicators, sometimes known as Leading Tactile Surfaces, orient pedestrians to the intended direction of travel with raised bars installed within the walking surface. These are intended to lead pedestrians with low vision or blindness along a path free of obstacles, and they frequently terminate at detectable warning mats. Typically, these are used when usual environmental cues such as curb or edge of pavement are missing, as is often the case at shared or flush streets or along sidewalk-level separated bike lanes. They are also used to provide directional orientation in large open spaces and to designate a continuous accessible route that avoids hazards. There is no ADA requirement for the use of directional indicators, but guidance for their use should conform with International Standard Organization (ISO) standard 23599 and existing FHWA guidance.

Horizontal Openings

Gratings and other utility covers should be placed outside of the sidewalk area to the maximum extent feasible, and where present in the PAR they must meet accessibility standards. Horizontal openings within a pedestrian access route (such as utility or drainage grates or joints) shall not be greater than 0.5 inches in diameter, with the elongated opening of the grate placed perpendicular to the predominant direction of travel.

4.4 Intersections and Pedestrian Crossings

A safe and intuitive pedestrian crossing incorporates the proper layout of design elements such as curb ramps, traffic control devices, intersection corner radii, and sight distance that accommodates all users. Both pedestrian and vehicular conditions factor into the design of pedestrian crossings. For example, where pedestrian volumes have the potential to be high, crosswalks and pedestrian queuing areas need to be of sufficient width and area to accommodate the volume of pedestrians. As vehicle volumes increase, roadway width may increase to provide additional travel lanes, thus increasing crossing lengths for pedestrians and their exposure to traffic, necessitating the use of supplemental traffic control devices to assist their crossing of the roadway. The following section discusses intersection elements and recommendations to provide effective crossings for pedestrians.

4.4.1. Design for Safe, Accessible, and Convenient Crossings

Whether marked or unmarked, crosswalks exist at all legs of all intersections represented by the extension of the property lines, curb lines, or edge of the traversable roadway through the intersection, including T-intersections, except where signs prohibit pedestrian crossings. Mid-block crossings require the marking of a crosswalk to establish a crossing. At all crosswalks, motorists are required to yield to pedestrians when the pedestrian is within the half of the roadway upon which the vehicle is traveling, or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger.

The following are characteristics of safe, accessible, and convenient pedestrian crossings:

- Proper visibility between approaching motorists and crossing pedestrians
- Appropriate frequency of crossing opportunities
- Minimal exposure to conflicts with motorists
- Minimal deflection in the line of travel
- Minimal delay to pedestrians waiting to cross at both signalized and unsignalized crossings
- Sufficient time for pedestrians to cross at signalized intersections
- High motorist yielding rates at uncontrolled crossings
- Clear communication to both drivers and pedestrians where pedestrians should cross the street
- Clear communication to pedestrians when it is safe to cross the street

Visibility

It is critical that pedestrians have adequate visibility of motorists approaching within travel lanes and that motorists in the travel lanes can easily see pedestrians waiting at intersections and mid-block crossings. Elements such as parked vehicles, fences, buildings, hedges, and walls can impede the visibility between motorists and pedestrians. When possible, these elements should be restricted or relocated to provide proper visibility. Designers should refer to Section 3.5 for evaluating sight distances between pedestrians and motorists.

Curb extensions or bump outs (see Section 4.5.4) can increase visibility at intersections and mid-block crossing locations, particularly for shorter pedestrians such as people using wheelchairs and children. ORC Section 4511.68 restricts parking within 20 ft. of a crosswalk at an intersection and within 30 ft. of, and upon the approach to, any flashing beacon, stop sign, or traffic control device. Depending on the site conditions, curb extensions can be designed to prevent motorists from parking within these restricted areas without removing parking.

Visibility is also impacted by larger corner radii, which by design place curb ramps and sidewalks farther back from the intersection. Section 7.2.4 discusses corner radii design which may improve visibility in some instances.

Illuminating crossings is necessary to ensure that pedestrians and motorists can see at night. It also improves pedestrians' sense of personal security and increases their visibility to approaching motorists when walking at night. When pedestrian crossings are expected to occur between dusk and dawn, designers should look to guidance described in Section 4.5.6 and the TEM for more information.

Frequency of Crossing Opportunities

Pedestrians should have safe, accessible, and convenient crossing opportunities at reasonable distances. Pedestrians will generally not travel out of direction and will cross at the most convenient location. A reasonable distance between crossing opportunities will depend on the land use context and pedestrian activity along the street. Distance is the primary factor in the initial decision to walk. The majority of pedestrian trips are 0.25 mi or less, with over 87 percent of walking trips less than 1 mi. Most people are willing to walk 5 to 10 minutes at a comfortable pace to reach a destination.[2]

In general, the frequency of crossing opportunities should be approximately the same spacing as the street grid in the surrounding area. In locations where the street grid results in block lengths over 600 ft. in length, and adjacent land uses that generate pedestrian traffic, mid-block crossings may be desirable to improve accessibility and walkability.[3] See Section 2.5.1 for identifying potential crossing locations and Section 4.4.2 for determining the appropriate crossing treatments.

Crossing Distance

Safe, accessible, and convenient pedestrian crossings are an essential component of pedestrian facility design. Short street crossings improve pedestrian safety and comfort by reducing their exposure time and reducing the potential of vehicle-pedestrian conflicts. Depending upon the signal timing phasing used, short street crossings may also reduce vehicle delay. Pedestrian crossing distances should be minimized to the greatest extent possible. Short crossing distances may be

achieved through one or more of the following treatments:

- Curb extensions– Section 4.5.4
- Median crossing islands – Section 4.5.3
- Realignment of crosswalks at offset or diagonal intersections
- Reducing wide vehicle and parking lane widths – Section 7.3
- Reducing number of vehicle lanes – Section 7.5

Pedestrian Delay

Minimizing pedestrian delay created by signal timing or a lack of gaps in traffic at unsignalized crossings decreases the likelihood that pedestrians will cross the street against a signal or without a sufficient gap in traffic. This may occur where delays exceed 40 seconds at signalized crosswalks and 20 seconds at unsignalized or yield-controlled crosswalks.[4] At signalized intersections, pedestrian delay can be minimized by maintaining short signal cycles (see Section 8.3.3). At uncontrolled crossings, designers should evaluate the crossing conditions to understand whether pedestrians will have a sufficient frequency and length of gaps in traffic; where crossing opportunities are insufficient, additional traffic control may be necessary.

Managing Vehicle Speeds and Conflicts

At both signalized and unsignalized intersections, steps should be taken to ensure that turning speeds are kept low and that adequate sight distance is provided for roadway users and pedestrians. This is critical given that the chance of severe injuries for the pedestrian goes up as vehicle speeds increase. The following treatments can be used to reduce speeds and improve visibility or eliminate conflicts between roadway users and pedestrians:

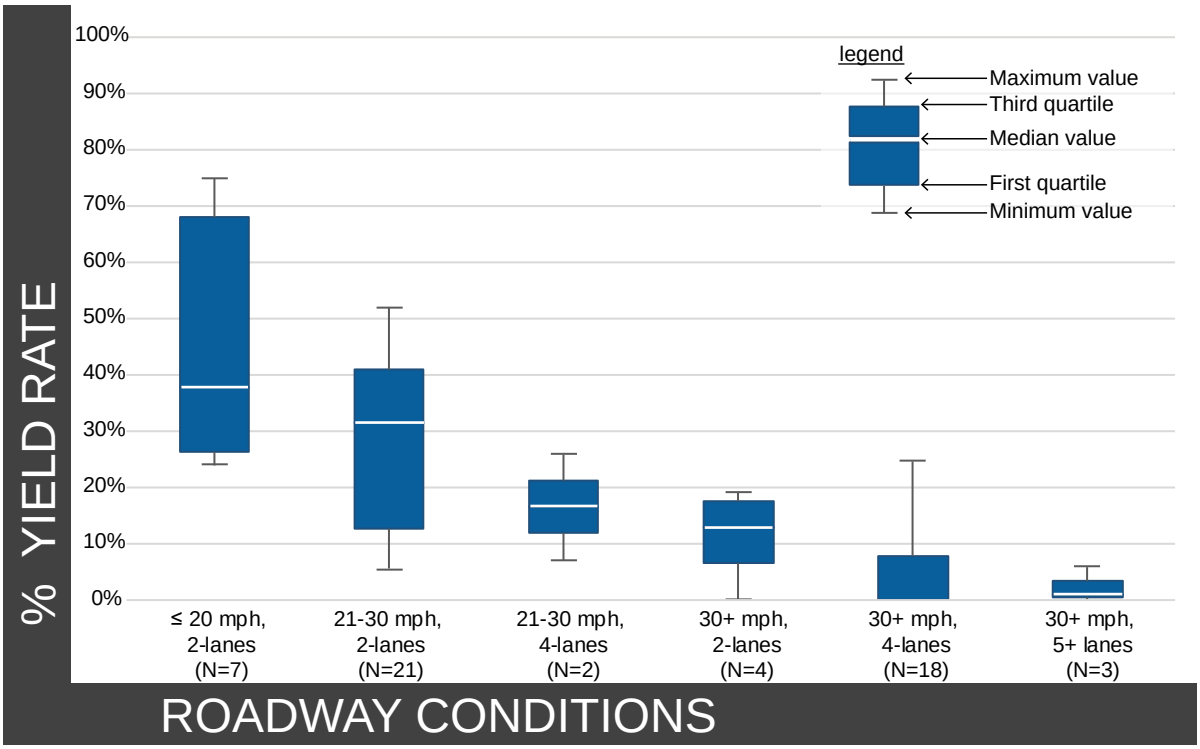
- Minimizing curb radii – Section 7.2
- Turning lanes and channelized right turns – Section 7.2.6
- Turning restrictions – Section 8.3.4
- Leading pedestrian interval – Section 8.3.4.1
- Median islands or hardened centerlines– Section 7.2.7
- Raised crossings – Section 4.5.5

4.4.2. Factors That Impact Motorist Yielding Rates

Research has identified motor vehicle approach speed, roadway configuration, pedestrian assertiveness, vehicle class, and race of the pedestrian as having a major influence on motorist yielding rates. As intersecting traffic volumes approach 9,000 vehicles/day, vehicle speeds exceed 30 mph, or the number of travel lanes to be crossed exceed two lanes, the rate of motorist yielding for pedestrians and bicyclists at uncontrolled approaches drops significantly; this can create crossing challenges for people walking or bicycling (see Figure 4-6).[5, 6] Additionally, the injury risk for pedestrians and bicyclists increases substantially when they are struck by vehicles operating at speeds over 30 mph (see Section 7.8). Research has also identified that drivers are less likely to

yield to black pedestrians than white pedestrians, increasing the injury risk for street users who are black.[7, 8] When street conditions exist that are not conducive to motorists yielding and pedestrians and/or bicyclists are likely to be present, additional design treatments and/or traffic control devices should be considered. Sections 4.4.3 and 6.4 provide recommendations for treatments based on the roadway context for pedestrian and bicycle crossings, respectively. Where pedestrians and bicyclist share a crossing, such as at a shared use path or side path, designers should follow the recommendations in Section 4.4.3.

Figure 4-6: Motorist Yielding at Uncontrolled Crossings Based on Roadway Characteristics



N=number of sites where observations were taken

*Traffic control at all study locations were limited to marked crosswalks and standard crossings signs (W11-1, W11-2, W11-15)

4.4.3. Selecting Pedestrian Crossing Treatments

Uncontrolled pedestrian crossings, including those crossings shared with bicyclists, such as shared use paths and side paths, should be designed with appropriate treatments and countermeasures to improve motorist yielding (see Section 4.4.2). Table 4-6 summarizes countermeasures which have been found to be effective at improving pedestrian safety based on research related to the number of motorist lanes, volumes, and operating speeds.

Table 4-6 should not be used to evaluate crossings without first establishing at which intersections or mid-block locations pedestrians desire to cross. Section2.5.1.2 provides guidelines for

determining existing and potential pedestrian crossing locations. Designers should recognize that the consideration of pedestrian accommodations and countermeasures is not based on a pedestrian volume threshold; instead, these features should be considered if there is a desire for pedestrians to cross.

For uncontrolled bicycle crossings, see Section 6.4. For signalized intersections, treatments such as crosswalks, crossing islands, alternative signal phasing, and other physical elements that manage vehicle speeds should be considered based on context. Refer to Chapters 7 and 8 respectively for vehicle speed management and traffic signal phasing.

Table 4-6: Application of Pedestrian Crash Countermeasures by Roadway Speed, Volume, and Configuration[20]

Roadway Configuration	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5 7 9	❶ ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1 High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2 Raised crosswalk
3 Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4 In-Street Pedestrian Crossing sign
5 Curb extension
6 Pedestrian refuge island
7 Rectangular Rapid-Flashing Beacon (RRFB)**
8 Road Diet
9 Pedestrian Hybrid Beacon (PHB)**

*Refer to Chapter 4, 'Using Table 1 and Table 2 to Select Countermeasures,' for more information about using multiple countermeasures.

**It should be noted that the PHB and RRFB are not both installed at the same crossing location.

This table was developed using information from: Zegeer, C.V., J.R. Stewart, H.H. Huang, P.A. Lagerwey, J. Feaganes, and B.J. Campbell. (2005). Safety effects of marked versus unmarked crosswalks at uncontrolled locations: Final report and recommended guidelines. FHWA, No. FHWA-HRT-04-100, Washington, D.C.; FHWA. Manual on Uniform Traffic Control Devices, 2009 Edition. (revised 2012). Chapter 4F, Pedestrian Hybrid Beacons. FHWA, Washington, D.C.; FHWA. Crash Modification Factors (CMF) Clearinghouse. http://www.cmfclearinghouse.org/; FHWA. Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE). http://www.pedbikesafe.org/PEDSAFE/; Zegeer, C., R. Srinivasan, B. Lan, D. Carter, S. Smith, C. Sundstrom, N.J. Thirsk, J. Zegeer, C. Lyon, E. Ferguson, and R. Van Houten. (2017). NCHRP Report 841: Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Board, Washington, D.C.; Thomas, Thirsk, and Zegeer. (2016). NCHRP Synthesis 498: Application of Pedestrian Crossing Treatments for Streets and Highways. Transportation Research Board, Washington, D.C.; and personal interviews with selected pedestrian safety practitioners.

4.4.4. Additional Considerations at Mid-block Crossings

Mid-block pedestrian crossings may be appropriate in a variety of contexts based on pedestrian desire lines, transit stop locations, land use context, and intersection spacing. Motorists are more likely to expect pedestrians at intersection locations and often drive at higher speeds in mid-block locations. Because of this, mid-block crossings should be used and designed to deliberately address pedestrian safety and improve motorist compliance.

Given the differences between intersection and mid-block crossings, there are several key considerations that designers must keep in mind in conjunction with those principles stated in Section 4.4.1:

- The crosswalk must be marked to establish a crossing
- The crossing location should be convenient for pedestrians
- Motorists should be alerted of the crossing as they approach it
- Pedestrians must be able to assess opportunities to cross
- All users must be aware of their responsibilities and obligations at the crossing and designers should ensure opportunities are provided to meet those responsibilities and obligations.

Designers should consider pedestrian volumes, motorist volumes, types of vehicles, traffic speeds, roadway characteristics (e.g., number of travel lanes, lighting), and adjacent land use context when determining if a mid-block crosswalk should be provided(see Section 2.5.1.2). Additionally, pedestrians have a strong desire to stay on their path of travel and do not want to go unnecessarily out of their way to utilize a crossing, so crossing locations should be placed at or near the pedestrian's desired path of travel.

4.5 Pedestrian Crossing Treatment Design

A safe and intuitive pedestrian crossing incorporates the proper layout of design elements such as curb ramps, traffic control devices, intersection corner radii, and sight distance that accommodates all users.

4.5.1. Markings

4.5.1.1 Crosswalk Markings

Crosswalk markings are a basic tool for directing pedestrians across the street and alerting motorists and bicyclists of crossing pedestrians. Engineering judgement should be used to determine when to mark a crosswalk. In general, marked crosswalks and other safety treatments should be prioritized at locations where pedestrians are vulnerable to conflicts with vehicles due to:

- High pedestrian and vehicle volumes, typical in town centers, at major bus stops, or near universities
- Vulnerable populations such as children, senior citizens, people with disabilities, or hospital areas

- Roadway conditions that make it difficult for pedestrians to cross, such as wide crossing distances, high traffic speeds, and/or complex intersection geometry

In some instances, crosswalk markings should be used in conjunction with other markings, signs, and warning beacons or signals. Refer to the OMUTCD and Table 4-6[9] to determine when to supplement crosswalk markings with other traffic control devices. Refer to the OMUTCD, TEM, and Chapter 8 of the MDG for additional information on the design and layout of pedestrian crossing traffic control devices.

There are two types of standard crosswalks:

- Standard (transverse) crosswalk markings – A standard crosswalk consists of two transverse (parallel) lines, each a minimum of 6 inches in width.
- High-visibility (longitudinal) crosswalk markings – A high visibility crosswalk consists of longitudinal lines striped parallel to the direction of travel. The longitudinal lines may be used alone or in addition to the transverse lines, thus creating a ladder-style crossing.

In general, longitudinal markings are more visible to drivers than the two transverse lines.[10] They are commonly used as a safety countermeasure to alert drivers to unexpected pedestrian crossings or particularly vulnerable pedestrian users (such as school zones or transit stops). Where the determination has been made to install crosswalk markings on ODOT-maintained highways, the longitudinal bar crosswalk should be used in the following situations:

1. At intersections where at least one approach has a speed limit of 35 mph or higher
2. At all established mid-block pedestrian crossings and with appropriate signing accompaniment

Refer to the TEM, Section 301-6.1, and OMUTCD, Section 3B.18, for line widths and spacing criteria for both standard and high-visibility crosswalks. At any marked crosswalk, curb ramps and other sloped areas should be wholly contained within the crosswalk markings. The crosswalk lines should extend the full length of the crossing. The TEM, Section 301-6.2 discusses optional aesthetic treatments that may be used between the white crosswalk lines. Longitudinal markings require more pavement marking material than transverse markings, and as a result have higher installation costs. Staggered spacing on longitudinal markings to avoid vehicle wheel paths can, however, reduce maintenance costs. See SCD TC 74.10 for spacing to avoid vehicle wheel paths.

4.5.1.2 Yield Markings

Yield lines may be used to indicate the point at which a bicyclist or motorist should yield in compliance with a yield sign, a Yield Here to Pedestrian (R1-5 or R1-5a) sign or a or Bicycle Yield to Peds (R9-6) sign. See OMUTCD, Section 3B.16 for guidance on yield markings.

An advance yield line can greatly reduce the likelihood of a multiple-threat crash, which occurs when a motorist stopped in one lane blocks the view of a second motorist. Advanced yield lines should be considered for any uncontrolled multi-lane crosswalk.

Advance yield markings should be placed 20 to 50 ft. in advance of a marked crosswalk to indicate where the vehicles are required to stop or yield and shall be paired with a Yield Here to Pedestrians (R1-5) sign.

4.5.2. Signing

Signage for the design of pedestrian facilities falls into two primary categories:

- Guide and wayfinding signs – see Section 5.7.1.
- Regulatory and warning signage for motorists – see the OMUTCD, Part 2 and Part 7 and the TEM, Section 200.

Pedestrian signage could include signing of ADA accessible routes, additional signage at crosswalks to clarify Walk/Don't Walk signal applications, and directional signage for pedestrian crossings to indicate which intersection leg walk signal is activated by the signal pushbutton. This signage helps pedestrians understand how to navigate an intersection or where to cross and can further define the pedestrian route in a corridor.

4.5.3. Crossing Islands and Medians

At signalized intersections, single stage crossings are preferred. Where a wide intersection cannot be designed or timed to accommodate a pedestrian crossing of the intersection at one time, a crossing island or median must be provided with a pedestrian refuge. A crossing island should be considered where crossing distances are greater than 50 ft. to better accommodate slower-moving pedestrians. When a crossing island is placed at a signalized crossing, use pedestrian recall to prevent "trapping" a pedestrian in the median (see Section 8.3.3). For multistage crossings at complex intersections and interchanges, see Chapter 9.

Raised medians are curbed medians located between travel lanes that serve as a pedestrian refuge space. Triangular channelization islands adjacent to right turning lanes can also act as crossing islands. Crossing islands can be coupled with other traffic calming features, such as partial diverters and curb extensions at mid-block and intersection locations (see Section 7.8.5).

The minimum width for a crossing island to provide an accessible refuge is 6 ft., measured from outside edge of the detectable warning surfaces, and the minimum width between detectable warning surfaces is 24 inches. Where medians are constructed using curbing and the detectable warnings are placed at the back of curb, the minimum width of the island is 7 ft., measured from curb face to curb face. Figure 4-7 illustrates a median crossing island with curbing where the detectable warning surface is placed at the back of the flush curb in the pedestrian refuge area. Figure 4-8 illustrates crossing islands with a 6 ft. width where detectable warnings are placed in line with the median island face of curb to meet accessibility requirements.

Crossing island width should be a minimum of 8 ft. on roadways with speeds of 50 mph or greater. The preferred minimum width is 10 ft., which accommodates bicyclists with trailers and wheelchair users more comfortably. Cut-through openings should match the width of the corresponding crosswalk. A "nose" that extends past the crosswalk toward the intersection is recommended to separate people waiting on the crossing island from motorists, and to slow turning motorists. Traffic control equipment, vegetation, and other aesthetic treatments may be incorporated, but must not obscure pedestrian visibility.

Figure 4-7: Median Crossing Island – Detectable Warning Surface Placed at Back of Curb

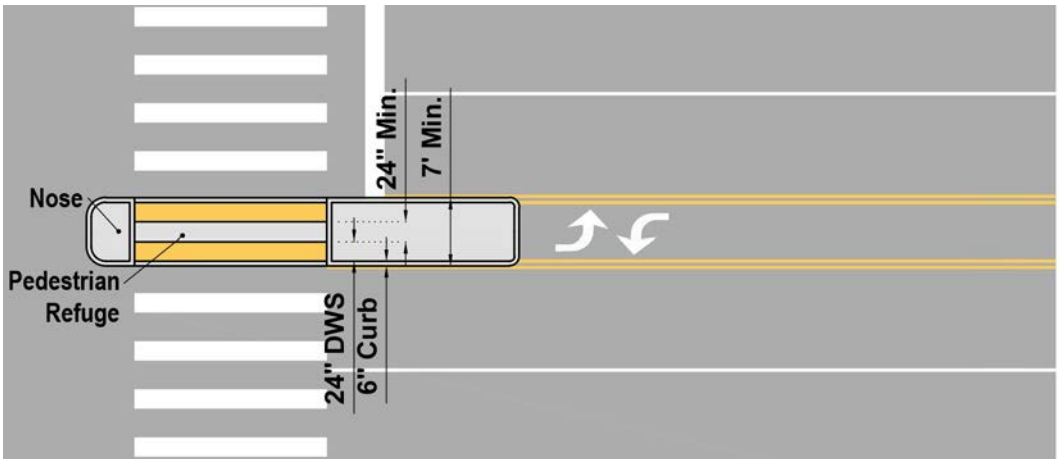
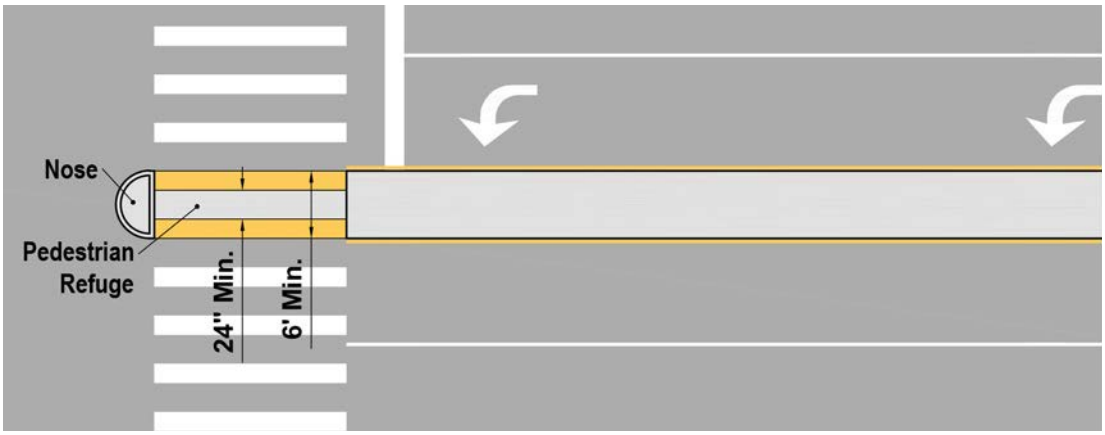


Figure 4-8: Median Crossing Island – Detectable Warning Surface Placed in Line with Island Face of Curb



4.5.4. Curb Extensions

On streets with on-street parking, curb extensions can be used at intersections and mid-block crossings to extend the sidewalk or curb line into the parking lane. Curb extensions reduce crossing distance for pedestrians and bicyclists, improve sight distance for all road users, and prevent parked cars from encroaching into the crosswalk area. At intersections, curb extensions can better control the effective turning radius (see Section 7.2.3) and can be used in conjunction with truck aprons (see Section 7.2.5).

Designers should consider the following for intersection and mid-block locations:

- Curb extensions are typically used where there is an on-street parking lane and its width is typically the width of, or 1 ft. less than, the width of the parking lane. Curb extensions may be considered for use where shoulders exist if bicyclists will not be operating on the shoulder.
- Mid-block curb extensions can be co-located with fire hydrants to maintain access to hydrants and to reduce impacts to on-street parking.

- Curb extensions can create additional space for curb ramps, low-height landscaping, and street furniture where sidewalks are otherwise too narrow. Care should be taken to ensure that street furniture and landscaping do not block motorists' views of pedestrians.
- Curb extension designs should facilitate adequate drainage, either by providing inlets upstream of the curb extension, providing grading that maintains drainage flows along the curb line, or by providing a drainage bypass channel beneath the sidewalk. The designer should consider factors such as maintenance in the selection of drainage facilities, as some options may be more prone to clogging and require more routine maintenance to function properly, and the ability of bicyclists or pedestrians to safely traverse the structures or grating.
- Designers should consider providing reflective vertical elements to alert drivers and snowplow operators to the presence of curb extensions.
- The length of a curb extension should extend at least 20 ft. on both sides of the crosswalk, but can be longer depending on the use desired within the extension (e.g., stormwater management, bus loading, restricting parking) or where additional parking restrictions are desired (e.g., where "Advance Yield Here To Pedestrians Sign" and yield lines are provided more than 20 ft. from the crosswalk).
- Painted curb extensions may be used as an interim measure and should be paired with edge objects such as flexible delineators to create a sense of enclosure and buffer from motor vehicle traffic.
- Approaches to curb extensions can be created as a straight taper or using reverse curves, though reverse curves are easier for snowplow operators to guide along without catching the plow edge.

See DWG 4-1 for additional design details for curb extensions.

4.5.5. Raised Crossings

Raised crossings are an effective strategy for reducing crashes between motorists and crossing pedestrians and bicyclists because they provide a vertical change in the roadway to slow the speeds of motor vehicles, increase visibility of vulnerable street users, and increase yielding behavior of motorists.[11,12] Raised crossings should be considered where motorists are required to yield the right of way to the crossing user. This includes locations such as:

- Unsignalized collector and local street crossings with side paths;
- Separated bike lanes along arterials;
- Crossings of driveways and alleys;
- Crossings of channelized right turn lanes and roundabouts; and
- Intersections where a large corner radius is required to accommodate large vehicles and truck aprons are not possible or desired.

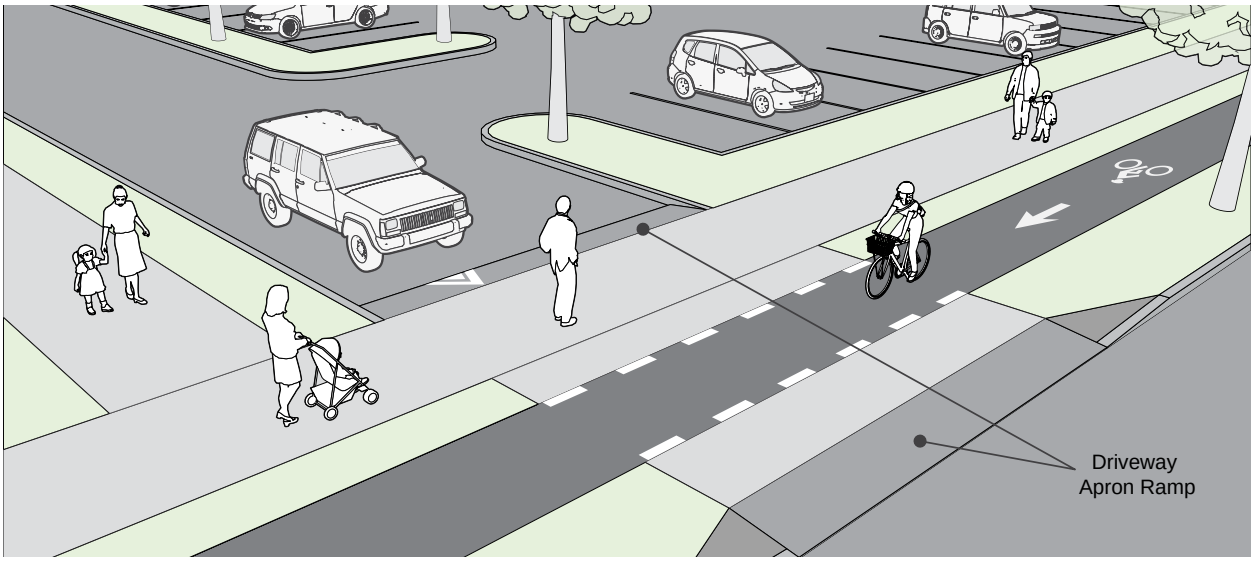
A target speed of less than 10 mph for the raised area should be used on roadways with a posted speed of 25 mph, but a target speed of 10 - 20 mph may be used where crossing volumes are low. A target speed of 10 - 20 mph for the raised area should be used on roadways with a posted speed of 30 mph. Raised crossings are not appropriate across streets where posted speeds are over 30 mph or where roadway grades exceed 8 percent. Designers should also consider the effects of raised crossings on drainage and pedestrian accessibility and must coordinate designs with emergency services.

Raised crossings are similar to speed tables and should have the following design characteristics (See Figure 4-9):

- A width of 10 to 12 ft. for the flat portion of the crossing is preferred. At a minimum, the width of raised crossings should be as wide as the connecting sidewalk and bicyclist path of travel (if relevant).
- For raised street crossings and raised driveway crossings where the driveway functions like a street, detectable warning surfaces must be provided at edges of sidewalks to indicate to pedestrians that they are exiting the sidewalk and entering the street.
- Designers should ensure that raised crossings meet accessible slope requirements.
- On-street parking and loading should be restricted at least 20 ft. before the marked crosswalk to provide adequate sight distance and visibility between people crossing and people driving, and to prevent drivers from having to pull forward onto the raised crossing to back into the first parking space. Designers should supplement parking restrictions with signage, pavement markings, and vertical elements such as flexible delineators or bollards where appropriate.
- Consider the use of raised crosswalks with curb extensions to maximize visibility and further slow traffic.
- On uncontrolled motor vehicle approaches, yield lines or speed hump markings should be used to indicate where motorists should yield to bicyclists and pedestrians.
- Provide a RAISED CROSSWALK sign.
- For driveways, the surface materials, color, and texture of the sidewalk, shared use path, and/or separated bike lane should extend through the crossing, maintaining visual continuity to encourage motorists to yield at the crossing.

See **DWG 4-2** for additional design details for raised crossings. See Section 7.8.3 to determine the appropriate target speed for the raised crossing.

Figure 4-9: Raised Driveway Crossings



4.5.6. Illumination

Providing lighting on pedestrian facilities improves user safety at night and at other times when there are low-light conditions. Additionally, the presence of public lighting has the added benefits of increasing the comfort, real and perceived safety, and security of people and property.

The TEM, Section 1100 discusses highway lighting. The text below summarizes key design guidance from that section that pertains to the design of lighting on or near pedestrian facilities.

1103-4 Land Use: The area surrounding a proposed lighted facility must be taken into account when considering the different types and intensities of light needed for a lighting plan. *American National Standard Practice for Roadway Lighting* (RP-8) sponsored by the Illuminating Engineering Society (IES) defines three general categories for land use: commercial, intermediate, and residential.

1103-6.2 Intersections: Lighting may be provided at intersections to enhance safety and to improve visibility of the intersection and approaches. Intersections with a high percentage of night crashes or a high volume of pedestrian traffic during the hours of darkness should be considered for lighting.

1103-6.3 Pedestrian walkways: Walkway lighting may be considered for security and aesthetic reasons. Walkway lighting may also include landscape or decorative lighting. Lighting of walkways may significantly increase use during the hours of darkness. Lower voltages (120 volts), vandal-proofing, and safety issues should be taken into consideration. For example, control centers should be securely padlocked, wiring and anchor bolts should be enclosed, and sharp edges and corners should be eliminated.

1140-4.6.4 Pedestrian Bridges: Generally, all pedestrian bridges should be lit. Since approaches to pedestrian bridges are not always accessible to maintenance vehicles, and since pedestrian bridge lighting is highly susceptible to vandalism, special consideration should be given to the location and protection of this type of lighting design.

Guidance related to foundations, decorative poles and luminaires, and luminance (foot-candles) are discussed in more detail throughout Section 1100 of the TEM.

4.5.7. Driveways and Alleys

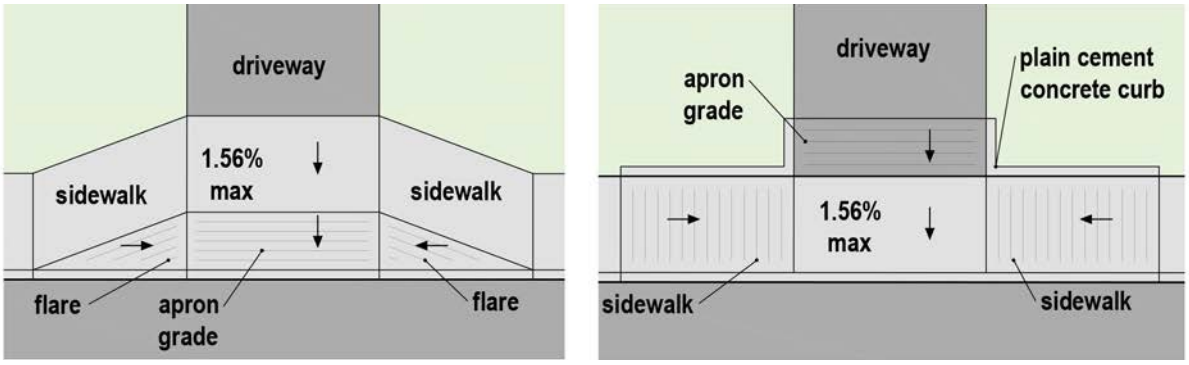
General driveway geometric design is discussed in L&D Manual Volume 1, Sections 803 and 804. The width and grade of the Pedestrian Through Zone should continue across residential and commercial driveways and alleys as shown in L&D Manual Volume 1, Figure 803-2. The driveway apron should be located within the Buffer Zone whenever possible.

It is preferable to maintain the sidewalk grade through the driveway. However, it may be appropriate to use a parallel ramp to meet driveway profile grading constraints; see L&D Manual Volume 1, Figure 803-3 for an example of grading using a parallel ramp. In existing constrained conditions, the Pedestrian Through Zone width may be reduced to 4 ft. And the sidewalk may be shifted back (See Figure 4-10). Cross slopes must meet accessibility requirements shown and

adequate drainage must be provided to keep the Pedestrian Through Zone clear of water and ice.

Driveway and alley widths should be minimized to reduce entrance speed and reduce exposure at vehicle access points. Detectable warnings are not typically provided at driveways and alleys, as they are intended to communicate to pedestrians with vision disabilities that they are entering or exiting a travel lane. However, in some instances the geometry or traffic control at a driveway makes the crossing comparable to a street, and PROWAG recommends providing detectable warnings for these locations. Section 4.5.9.4 discusses when it may be preferable to include detectable warnings at driveways.

Figure 4-10: Sidewalk Configurations at Driveways in Constrained Locations



4.5.8. Parking Restrictions

Setting back parking and other visual obstructions from intersections and driveways provides appropriate sightlines and visibility between pedestrians and motorists. This can be achieved by restricting parking or stopping near crossings, intersections, and driveways. Parking can be restricted by using signs, pavement markings, flexible delineators, and/or curb extensions. Parking restrictions should be:

- Signed or marked to prohibit parking for a minimum of 20 ft. on each side of a marked crosswalk or driveway, and for a minimum of 30 ft. prior to a flashing beacon, stop sign, or traffic control device. Additional space may be required based on engineering judgment or based on local regulations.
- Signed or marked to prohibit parking for a minimum of 5 ft. on each side of a minimum use driveway if there is a history of illegal parking behaviors at a particular location, or based on engineering judgment.

Designers may also consider the following:

- Using engineering judgement to determine if greater parking restrictions and fewer visual obstructions should be provided based on prevailing motor vehicle speeds or other intersection features.
- Using curb extensions to prevent motor vehicles from parking or stopping in restricted areas.
- When retrofitting existing pavement areas to be parking restricted areas, surface treatments

(e.g., paint, epoxy coated aggregate), low height vertical elements (e.g., flex posts), bicycle parking, or multimodal hubs can be considered within restricted areas.

The application of one or more of these treatments may also help mitigate illegal parking near intersections.

4.5.9. Curb Ramps and Detectable Warning Surfaces

Curb ramps are an essential element for pedestrian accessibility that also serve to assist any person using a wheeled device (bicycle, stroller, dolly, etc.) to transition between the sidewalk and roadway. Where provided, all newly constructed or modified curb ramps must be ADA compliant to the extent practicable and should be designed to the least slope practical considering the curb height, available corner area, and underlying topography.

ODOT's standards related to ADA dimensional criteria are based on PROWAG. Additional guidance on the design of accessible pedestrian facilities is available from the Department of Justice and FHWA[13,14].

4.5.9.1 Curb Ramp Locations

ORC Section 729.12 requires that all new or reconstructed curbs shall have curb ramps at each pedestrian crosswalk so that the sidewalk and street blend to a common level.

Curb ramps shall be provided on all plans where curb and sidewalks or walkways are being constructed, reconstructed, or altered at intersections and other major points of pedestrian curb crossing such as mid-block crosswalks.

Curb ramps are required if:

- A project has curbs, pedestrians are allowed, and sidewalks are present
- A project has curbs, pedestrians are allowed, and no sidewalks are present but a pushbutton is present. In this scenario, a graded earth curb ramp should be provided as shown in Figure 4-17.
- It is a resurfacing project and conditions are met as outlined in ODOT Policy 21-003(P) *Curb Ramps Required in Resurfacing Plans*.

It is desirable to provide an accessible route for persons with disabilities. When a curb ramp is built on one side of a street, a companion curb ramp is required on the opposite side of the street. Therefore, when normal project or work limits end within an intersection, the work limits must extend to allow construction of companion ramps. The basic requirement is that a crosswalk must be accessible via curb ramps from both ends, not one end only. In most cases, curb ramps will be installed in all quadrants of an intersection.

When pedestrian facilities are to be constructed or reconstructed as part of an alteration project, the facilities shall be designed to accommodate persons with disabilities to the greatest extent practicable. The pedestrian environment must be designed to accommodate the needs of all users, some of whom have a broad range of mobility, physical, and cognitive skills.

4.5.9.2 Curb Ramp Components

The basic components to the standard curb ramp design are explained here and depicted on Figure 4-12.

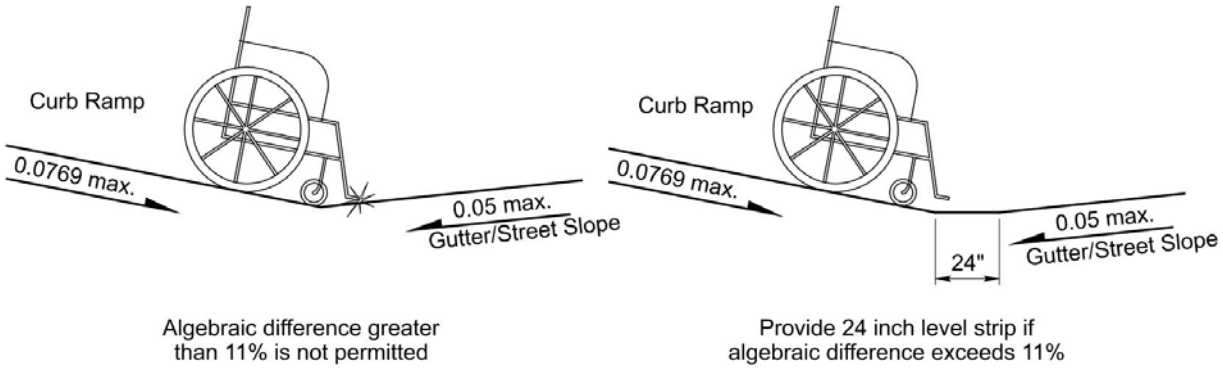
Ramps – Ramps serve as the primary travel path for wheelchair users and other pedestrians traversing the curb between the sidewalk and the roadway. The grade of a ramp shall not exceed 8.33 percent. The cross slope shall not be greater than 2 percent. The minimum width of a curb ramp is 4 ft. To ensure ramp slopes do not exceed the maximum, ramps should be designed for 7.69 percent and 1.56 percent for running and cross slopes, respectively, to account for construction tolerances.

Gutters – Gutters facilitate the movement of water from the roadway into the local drainage system. Gutters require a counter slope (i.e., roadway cross slope) at the point at which the ramp meets the street for proper drainage. This counter slope should be 2 percent or less where possible, but shall not exceed 5 percent, and the change in angle must be flush, without a lip, raised joint, or gap. Lips or gaps between the curb ramp slope and counter slope can arrest forward motion by catching caster wheels or crutch tips. The algebraic difference between the ramp slope and the gutter counter slope cannot exceed 11 percent, or a 24 inch level strip must be provided between the two slopes. See Figure 4-11 through Figure 4-15.

Landings - Landings provide a level area for wheelchair users to maneuver into or out of the curb ramp and can serve as turning areas. A level, 5 ft. square landing is preferred; a 4 ft. square landing is the minimum. Level landings are required at the top of ramps with slopes designed for 1.56 percent slope (2 percent maximum) in any direction.

Flares - Curb ramp flares are graded transitions from a curb ramp to the surrounding sidewalk. Flares are not intended to be wheelchair routes, are considered a non-walkable surface, and often serve as one of the cues used to identify the presence of a curb ramp. In most instances, flares are not required for curb ramps. When provided, flare slopes shall not exceed a 10 percent slope. Side flares are advisable where pedestrian traffic may cross runs to prevent tripping hazards. Side flares are essential in alterations when space for a top landing (36 inches deep minimum) is not available; in this instance, side flares with a max slope of 8.33 percent are necessary to accommodate wheelchair maneuvering that will partially occur at flares in the absence of full landing space at the top of the ramp unless a parallel-type curb ramp is provided. Parallel curb ramps provide an alternative in such conditions.[15, 16]

Figure 4-11: Counter Slope



4.5.9.3 Curb Ramp Types

There are four types of curb ramps currently used in street corner designs:

- Perpendicular (Tier 1)
- Combined (Tier 2)
- Parallel (Tier 3)
- Diagonal (Tier 4)

Ramp types are categorized above in tiers by preferred order of use, with Tier 1 being the most desirable. The designer should not use a lower tiered ramp without first determining and having justification that the upper tiered ramp is not constructible. Justification may be based on factors such as the presence of drainage features, utilities, right-of-way restrictions, geometric impacts, or operational issues.

In all cases, curb ramps should be located entirely within the marked crosswalks (where they exist). Drainage grates or inlets should not be located within the crosswalk area, as wheelchair casters or cane tips could get caught.

Tier 1: Perpendicular curb ramps (Type A1 and A2 in Standard Construction Drawing BP-7.1) are generally perpendicular to the curb. Users will generally be traveling perpendicular to vehicular traffic when they enter the street at the bottom of the ramp. Perpendicular curb ramps can be designed as directional curb ramps that align pedestrians with the crosswalk orientation and eliminate the need for people in wheelchairs to reorient themselves within the street. Non-directional ramps are perpendicular to the curb even on corner radii, which means they do not provide a straight path of travel for pedestrians. If the angle of the curb ramp is greater than 20 degrees to the angle of the crosswalk (i.e., angle Z in Figure 4-12), a directional curb ramp should be considered. All perpendicular ramps have the disadvantage of requiring a level landing that takes up additional right-of-way at the top of ramp. Perpendicular ramps are generally the best design for pedestrians, provided that a minimum 4 ft. landing is available for each approach.

Figure 4-12: Perpendicular Curb Ramp Types: Non-Directional (top) and Directional (lower)

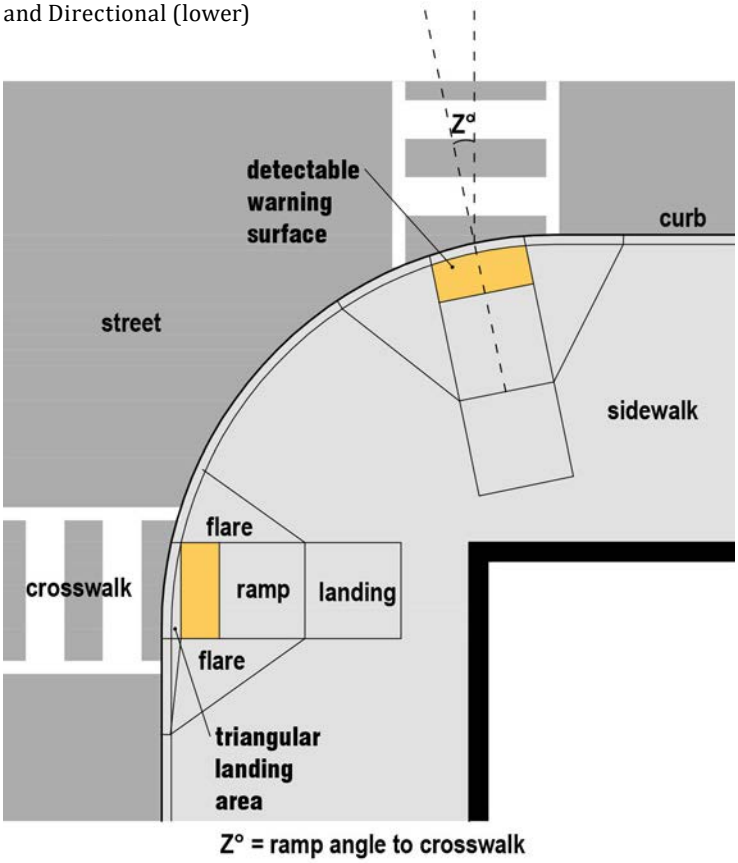
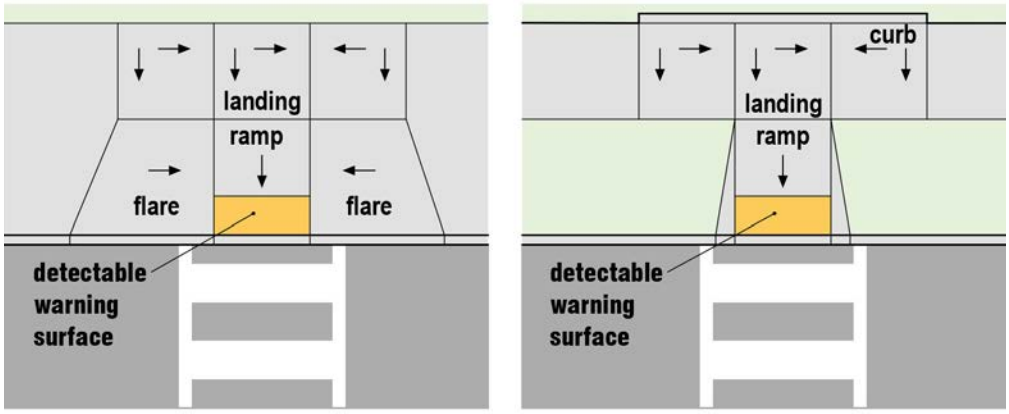


Figure 4-13: Combined Curb Ramp Examples



Tier 2: Combined curb ramps (Type C1 and C2 in Standard Construction Drawing BP-7.1) use features of both perpendicular and parallel curb ramps (see Figure 4-13). This design can be advantageous when dealing with a narrow sidewalk or a steep grade. These ramps may be more expensive and complicated to install.

Tier 3: Parallel curb ramps (Type B1, B2, and B3 in Standard Construction Drawing BP-7.1) have one ramp (B1 and B3) or two ramps (B2) leading down towards a level landing at the bottom, with a level landing at the top of each ramp (Figure 4-14). They can be installed where the available space between the curb and property line is too tight to permit the installation of both a ramp and a landing, and they are effective on steep terrain or at locations with high curbs. Unfortunately, sidewalk users have to negotiate two ramp grades. Since the landing is depressed and level, drainage of the ramp landing at the street must be carefully designed.

Figure 4-14: Parallel Curb Ramp Example

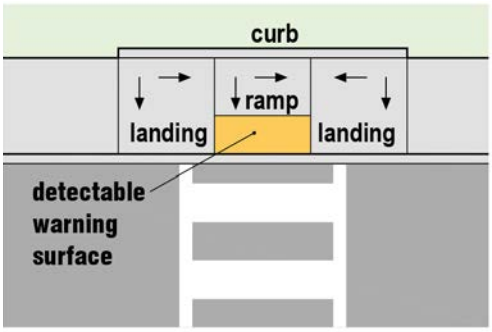
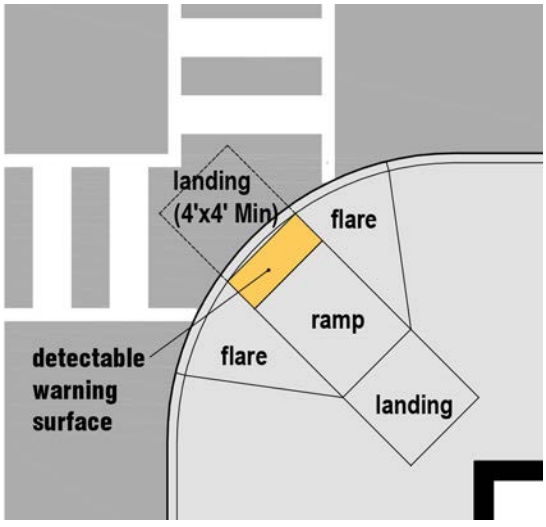


Figure 4-15: Diagonal Curb Ramp Example



Tier 4: Diagonal curb ramps (Type D in Standard Construction Drawing BP-7.1) are a single curb ramp that is located at the apex of the corner (Figure 4-15). Diagonal curb ramps are not acceptable designs for access to new sidewalks, but may be applied in retrofit locations where a pair of perpendicular ramps is not feasible due to existing site constraints. This design directs a visually impaired person away from the crosswalk and into traffic. Therefore, the entire lower landing area must fall within the crosswalk that the ramp serves and cannot be located in the traveled lane of traffic.

4.5.9.4 Detectable Warnings

Detectable warnings are standardized surface features on walking surfaces to communicate to people with vision disabilities that they are approaching a crossing.

Truncated domes are specified as the detectable warnings to be used at the interface between the Pedestrian Through Zone and the roadway. They are to be included in all connections to all street crossings to mark the street edge where a Pedestrian Through Zone crosses a vehicular way.

Detectable warnings should be used:

- At the base of curb ramps,
- At the border of median crossing islands,
- At the edge of depressed corners,
- At the border of raised crosswalks and raised intersections,
- At street crossings for shared use paths,
- Where sidewalks cross railroad tracks,
- At blended transitions, and
- At signalized driveways.

Considerations for detectable warnings at driveways include the following:

- Detectable warnings should not be indiscriminately applied at minor driveway locations or alleyways that appear and function more like a sidewalk than a street crossing. This may be confusing and a nuisance to pedestrians with vision disabilities.
- Detectable warnings should be used at driveways with heavy traffic, a signal, a stop sign, or a yield sign that make their crossing comparable to a street.

Truncated dome dimensions, location, and alignment can be found on Standard Construction Drawing BP-7.1.

Detectable warnings placed within the shoulder are appropriate to provide guidance for pedestrians with vision disabilities to identify the street crossing if the shoulder is the designated PAR.

4.5.9.5 Blended Transitions

A blended transition is a raised pedestrian street crossing, depressed corner, or similar connection between the pedestrian access route made at the level of the sidewalk and crossing a street where the grade is 5 percent or less, such as on an uncurbed roadway. ADA requirements for cross slopes and detectable warnings for blended transition are similar to those of a curb ramp. A landing is not required for a blended transition. Blended transitions must be wholly contained within the pedestrian street crossing served.

Blended transitions can occur at intersection corners as well as at other street crossings. Blended transitions can be advantageous for pedestrians for several reasons. With the flat grade, no landing or turning space is needed at the top or bottom of the transition area. Maintaining the same

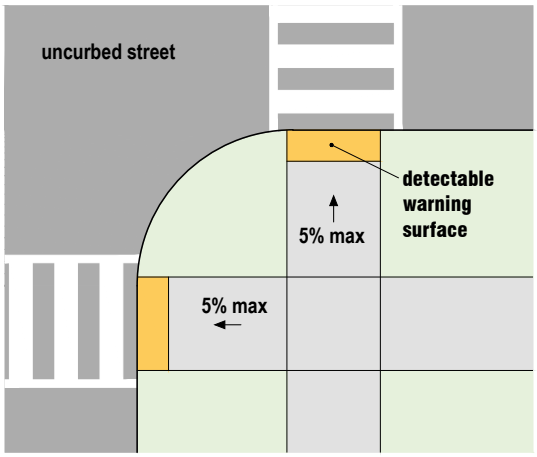
sidewalk and ramp running slopes also simplifies the overall facility design and increases ease of use. The flatter design also eliminates sharp grade breaks between the walk and the traditional curb ramp area.

At intersection corners, attempts to install actual curb ramps should be made before blended transition options are examined.

It is important to note that blended transitions between pedestrian travel ways and vehicular travel ways can create difficulties for pedestrians by providing a large area where the corner and street are at the same elevation. This can make it much more difficult to detect the boundary between the sidewalk and the street for persons with vision disabilities. Similar to diagonal curb ramps, depressed corners can make it more difficult for motorists to determine in which direction a pedestrian intends to cross the street. Figure 4-16 illustrates a blended transition at an intersection corner.

To delineate the boundary between the pedestrian area and the vehicular area, detectable warning mats shall be placed along the entire extent of the depressed area, as shown Figure 4-16. It is critical to ensure the detectable warning mats encompass the entire length of the area flush with the adjacent roadway so the boundary between the pedestrian area and vehicular area is clear to pedestrians with vision disabilities.

Figure 4-16: Blended Transition Example



Blended transitions may also be used at raised pedestrian street crossings or raised crosswalks. To provide a clear delineation between the pedestrian walkway and the crossing or crosswalk, the detectable warning mat shall extend across the entire width of the interface between the sidewalk and the raised crossing or crosswalk.

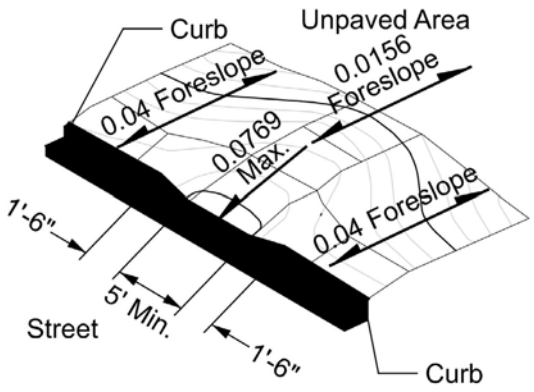
Blended transitions may also be found at street crossings near major pedestrian generators such as sports arenas, transit hubs, convention centers, college or university campuses, or pedestrian-centric commercial areas. Blended transitions in these areas permit large volumes of pedestrians to cross roadways at a time. Similar to the raised crosswalk and intersection applications, truncated dome mats shall be placed along the full length of the transition area to delineate the boundary between pedestrian and vehicular facilities.

4.5.9.6 Curb Cuts

Pedestrian curb cuts, or dropped curbs, eliminate the vertical curb face and may facilitate a pedestrian walking within the roadway to exit the roadway. Pedestrian curb cuts should be placed where the pedestrian route is intended to continue across a roadway, but where a receiving curb ramp and sidewalk do not currently exist. This can be at the roadway edge, at a median or

roundabout splitter island, or anywhere a curb presents a vertical face that is not traversable by a mobilPedestrian Curb Cuts. Figure 4-17 describes the required widths and slopes for a pedestrian curb cut.

Figure 4-17: Pedestrian Curb Cuts



4.5.9.7 Curb Ramp Design Waiver

PROWAG recognizes that it is not always practicable to fully meet ADA dimensional requirements due to physical constraints, "Existing physical constraints include, but are not limited to, underlying terrain, right-of-way availability, underground structures, adjacent developed facilities, drainage, or presence of notable natural or historic features (R202.3.1)". In cases where it is not possible to meet ADA requirements, the pedestrian facilities shall be designed and constructed to meet ADA requirements to the maximum extent practicable.

Disproportionate cost to provide an accessible path of travel can also be a factor in a decision to deviate from ADA requirements. Disproportionate cost is defined to be "the additional cost of alterations to provide an accessible 'path of travel' to the altered area is disproportionate when it exceeds 20 percent of the cost of the alteration to the 'primary function' area." (R202)

Existing sidewalks where the maximum ramp slope is not feasible due to site constraints (e.g., utility poles or vaults, right-of-way limits) may be reduced as follows:

- 10:1 for maximum rise of 6 inches
- 8:1 for maximum rise of 3 inches
- 6:1 over a maximum run of 2 ft.-0 inches for historic areas where a flatter slope is not feasible

To prevent chasing the grade indefinitely, the transition from existing sidewalk to the curb cut is not required to exceed 15 ft. in length.

ODOT has developed a design waiver process to identify the circumstances preventing the ability to provide accessible facilities. Prior to the development of the waiver, the designer must consider alternatives to achieve accessibility (including those values stated above) and show that the accessible design cannot be achieved. The waiver form and directions for completing it can be found on ODOT's ADA Resources website. Specific documentation requirements and retention practices are discussed in subsequent sections.

Documentation Requirements

In cases where it is not practicable to meet all ADA dimensional requirements, the constraints shall be documented in an ADA waiver form. Waiver forms should be created either in design or during construction at the time it becomes known that a constraint will preclude a pedestrian facility from meeting ADA requirements. In either case, during design or during construction, the District Design Engineer will be responsible for review and approval or denial of ADA waivers.

A project's scope and Purpose and Need should be a consideration when evaluating an ADA waiver. The scope of the project can be an important consideration in determining if meeting ADA requirements is practicable. For example, resurfacing projects are considered alteration projects that require the updating of pedestrian curb ramps. If the scope of a resurfacing project, however, does not require the purchase of additional right-of-way, in this example it is not practicable to purchase right-of-way. The project should make as many ramps fully compliant to ADA requirements as possible without purchasing right-of-way. The remaining ramps shall be reconstructed to ADA requirements to the maximum extent feasible without the purchase of right-of-way. Those ramps not meeting the ADA requirements shall have an approved ADA waiver form completed and signed by the District Design Engineer for each non-compliant pedestrian feature. Future projects at a location with a waiver should determine whether the feature could be made compliant based on the scope of the project, recognizing that there are some locations where compliance may not be possible.

Where infeasible to construct a pedestrian facility to ADA standards, a waiver form is required regardless of governing authority. Identified infeasible facilities shall be added to the ADA collector application and a waiver form completed by the district with information supplied by the governing authority. The final approval for a waiver, including waivers on local projects utilizing federal funds, rests with the District Design Engineer.

Identified non-compliant pedestrian facilities do not require a waiver until a project impacts the facility and improvements are considered infeasible.

Construction tolerances are included in ODOT standard construction drawing BP-7.1 and are slightly more conservative than PROWAG standards. A waiver is required when a pedestrian facility does not meet PROWAG standards. ADA waivers shall be recorded on the title sheet of construction plans per L&D Manual Volume 3, Section 1302.15.

Approved ADA waiver forms shall be attached to their specific Asset ID in the ADA Collector Application database. Future projects with an appropriate scope and Purpose and Need should reference previously approved waiver forms and upgrade the pedestrian facilities to full ADA compliance where possible.

4.5.10. Ramps and Landings

At times, sidewalks that are not adjacent to roadways may exceed a 5 percent longitudinal slope. Where this occurs, the pedestrian access route is treated like a ramp. Per PROWAG R407, the maximum running slope, horizontal run, and vertical rise are summarized in the table below. It is advised to provide a ramp with the least possible running slope in order to accommodate the widest possible range of users.

Table 4-5: Summary of ADA Compliant Ramp and Landing Design Elements

Design Element	Criteria
Running Slope	5 percent minimum 8.33 percent maximum
Rise	2.5 ft. maximum
Landing (Provide at top and bottom of ramp)	1.56 percent running and cross slopes 5 ft. minimum length Width matches width of ramp
Intermediate landings for turning maneuvers	5 ft. minimum length and width 1.56 percent running and cross slopes

Landings should be clear of any obstructions, such as manholes, utility boxes, or valves, and ramps and landings should meet the surface requirements for pedestrian access routes as defined in PROWAG and Section 4.3.3.

If the pedestrian access route does not have sloped grading adjacent to the ramp and has a vertical drop of more than 6 inches, a railing is required to protect pedestrians from stepping off the edge of the ramp. Dimensions for the railing can be found in PROWAG Section R-409.

For shared use paths/trails design guidance, see Chapter 5 of this guide.

4.6 Parking

ODOT's ADA Design Resources site establishes on-street parking accessibility requirements and contains an inventory of parking in ODOT's public right-of-way. On-street parking design follows ADAAG Section 502 and PROWAG Sections R211.4, R214 and R309. These sections address the number of accessible spaces, parking stall width, length, loading zones, and access aisles. Markings, signage, and symbols are discussed in the OMUTCD, Section 3B.20.

Accessibility for parking design can also include access to any parking meters or pay kiosks. Meters and kiosks require clear spaces adjacent to the meter or kiosk face, with clearance widths and reach and height meeting PROWAG Section R404 Clear Spaces requirements. Obstructions around meters and pay kiosks must be avoided and protrusions must meet accessibility requirements stated in PROWAG Section R402.

4.7 Overpasses and Underpasses

4.7.1. Sidewalks for Bridges/Underpasses

Provisions should always be made to include some type of walking facility as part of a vehicular bridge or underpass, if only as an emergency exit path. Wherever possible, sidewalk widths across bridges and through underpasses should be the same as the clear width of the existing connecting sidewalks.

Designers should refer to the ODOT Bridge Design Manual and the L&D Manual Volume 1, Section

302 for specific guidance on bridges and assessing the cross-section.

4.7.1.1 Sidewalks on Bridges

Walks should be provided on bridges located in urban, suburban, and rural town areas having curbed typical sections under the following conditions:

1. Where there are existing walks on the bridge and/or bridge approaches, or
2. Where evidence can be shown through local planning processes, or similar justification, that people do walk on the bridge or will based on changing land use context.

Walks on bridges should be at least 6 ft. wide in residential areas and 8 ft. wide in commercial areas measured from the face of curb to the face of parapet. The minimum width should never be less than 5 ft.

In rural areas or at other sites where flush shoulders approach a bridge and light pedestrian traffic is anticipated on the shoulders, the shoulder width should be continued across the bridge using the preferred lateral clearance from L&D Manual Volume 1, Figure 302-1, or greater if deemed appropriate. A raised walkway should not be used in these areas.

4.7.1.2 Sidewalks under Bridges

The criteria for providing walks at underpasses are the same as described above for walks on bridges. An exception is in areas where there are no approach walks. Space should be provided for future walks but walks generally will not be constructed with the project unless there is concurrent approach walk construction. Where the approach walks at underpasses include a tree lawn, the tree lawn width may be carried through the underpass wherever space permits.

4.7.2. Pedestrian Only Grade Separated Crossings

When pedestrian facilities cross certain barriers, grade-separated pedestrian crossings are desirable and may be necessary. Common barriers include freeways, arterials, rivers, and railroads where there is an observed or expected pedestrian demand but no suitable at-grade locations to cross within the vicinity.

Construction of grade-separated crossings can be extremely costly and disruptive to the pedestrian path of travel, and they can invite vandalism or crime if not designed well. Additionally, they are structures that require maintenance and are vulnerable to natural disasters; for example, underpasses could flood. For these reasons, the design of a grade-separated crossing should be carefully considered.

Due to the high costs of constructing pedestrian-only structures, they should be considered only where other more standard and/or less costly solutions are not acceptable. Both pedestrian overpasses and underpasses need to meet accessibility requirements for maximum slopes. The most common design option is to include either ramps and landings or elevators to address changes in grade for pedestrians. A second design option may be considered to more easily meet accessibility requirements. This involves lowering or raising the road such that the pedestrian facilities remain at grade and the roadway is placed above or below the pedestrian route; however,

this approach will result in a larger area of impact within the roadway to allow roadway slopes to ramp up and down at the pedestrian facility. The third design option is to alter both facilities, lowering or raising the road while doing the opposite for the pedestrian route, thus minimizing the vertical change in elevation for both the pedestrian and motorist facilities.

Freeways should not have pedestrian crossings at grade and may require the occasional use of separate pedestrian structures.

Underpasses that are below grade should provide clear sight distances to and through the underpass. A minimum width of 14-16 ft. is desirable, but longer tunnels should be wider for personal security. Likewise, vertical clearance of 8 ft. is sufficient for short tunnels, but longer ones may need 10 ft. Heights of bicyclists or maintenance and emergency vehicles may also need to be addressed. Drainage must be carefully considered.

Both pedestrian overpasses and underpasses should be adequately illuminated. See additional details on illumination in Section 4.5.6.

4.7.2.1 Guidelines

Experience has shown that the primary location for a pedestrian overpass/underpass is an urban area outside the central business district. Such a pedestrian crossing may be considered when the following conditions exist:

1. The community has expressed a strong desire for a pedestrian crossing.
2. A reasonable alternate route for pedestrians is not available.
3. There is no signal, stop intersection, or pedestrian crossing available within 600 ft. of the proposed location.
4. Pedestrians are prevented from crossing at grade, such as at freeways and rivers.
5. Physical conditions permit construction and ADA accessible grades are achievable.
6. The traffic volume and pedestrian volume are above those required to warrant the installation of pedestrian signals as stated in the OMUTCD. This stipulation can be waived in special cases such as when sight distances are limited.
7. Where there are a large number of pedestrians who must regularly cross a high-speed, high volume roadway.

Designers working on a pedestrian-only bridge should refer to Sections 303.2, 309.4/309.4.3.3, 309.5.3, 309.5.5.1, and 310.8 of the ODOT *Bridge Design Manual* and other national guidance[17] for relevant information on pedestrian bridges, bicycle and pedestrian bridges, and railing/fencing guidance for pedestrian bridges or vehicle bridges with pedestrians present.

4.7.3. Barriers and Railings for Pedestrian Facilities

Railing requirements differ based on the expected design user, the type of facility, and the slope. To maintain minimum ADA requirements on sloped approaches to a grade-separated facility, handrails must be provided at a continuous height of 34 to 38 inches above the walk surface. A second set

of handrails at a maximum height of 28 inches may be considered if children are expected to be regular users of the facility. If two handrails are provided, the minimum vertical clearance between the two is 9 inches to reduce the likelihood of entrapment.

If the primary purpose of a railing on an overpass is to separate users from a drop-off, the minimum height is 42 inches above the walk surface. If bicyclists are also expected on the overpass, designers should refer to Chapter 5 for guidance on shared use paths.

4.8 Work Zones

Accessible routes should be maintained through construction sites or pedestrian detour routes should be provided. These routes can be along the existing pedestrian route or an alternative temporary route. The requirements for pedestrian access route widths, grades, cross slopes, and surface treatments through or around work zones must all meet the requirements detailed in PROWAG Sections R300 and R400. Per Chapter 6 of the OMUTCD, agencies must provide reasonably safe and effective movement for all roadway users. If the existing pedestrian route cannot be maintained, information about alternate routes should be provided. This must include access to temporary bus stops, reasonably safe travel across intersections, and other routing issues. Barriers and channelizing devices that are detectable by people with visual disabilities must be provided. Curb ramps and detectable warnings shall be implemented where applicable. The following items should be considered to facilitate an accessible pedestrian route through or around work zones in addition to the features mentioned above:

- Advanced warning and guidance signs
- Adequate illumination and reflectors
- Use of temporary walkways
- Channeling and barricading to separate pedestrians from traffic
- Adequate barricading to prevent a person with vision disabilities from entering work zones
- Accommodation for pedestrian through work zones
- Temporary striping, detectable warning surfaces, and pedestrian signalization for crosswalks; adjusted pedestrian crossing times for modified crosswalk lengths

Guidance for providing pedestrian facilities through or around work zones is discussed in the TEM and the OMUTCD.

The TEM, Section 603 provides guidance on pedestrian and worker safety. This section notes that in work zones “where pedestrian traffic is present, pedestrian safety and needs must be addressed.” OMUTCD, Sections 6D.01 and 6D.02 provide additional details.

The TEM, Section 606-21 provides additional guidance on the types of temporary traffic control zones that are needed for work affecting pedestrian and bicycle facilities. OMUTCD, Sections 6G.04 and 6F.74 provide additional details.

ODOT SCD MT-110.10 and OMUTCD, Figures 6H-28 and 6H-29 show typical traffic control device uses and techniques for pedestrian movement through work areas.

4.9 Additional Resources

The following resources provide information about the design of pedestrian facilities:

- ODOT Design Resource Reference Center[18] – provides direct links to design guides, specifications and standard drawings.
- ODOT ADA Design Resources[19] – provides a summary of available resources, trainings, design guidelines, requirements, facility databases, and standard drawings specifically related to the ADA.

Chapter 4 Endnotes

1 FHWA Small Town and Rural Design Guide

2 FHWA. Summary of Travel Trends, 2017 National Household Travel Survey. FHWA-PL-18-019. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2011. Available online at https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf.

3 FHWA Achieving Multimodal Networks

4 NACTO Urban Street Design Guide

5 Bertullis, T. and D. Dulaski. Driver Approach Speed and its Impact on Driver Yielding to Pedestrian Behavior at Unsignalized Crosswalks. *In Transportation Research Record 2464*. TRB, National Research Council, Washington, DC, 2014.

6 Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord. *National Cooperative Highway Research Program Report 562: Improving Pedestrian Safety at Unsignalized Crossings*. NCHRP, Transportation Research Board, Washington, DC, 2006.

7 Goddard, T., K. B. Kahn, and A. Adkins. Racial Bias in Driver Yielding Behavior at Crosswalks. *Transportation Research Part F: Traffic Psychology and Behavior*. Transportation Research Board, Washington, DC, 2015.

8 Coughenour, C., S. Clark, A. Singh, E. Claw, J. Abelar, and J. Huebner. Examining Racial Bias as a Potential Factor in Pedestrian Crashes. *Accident Analysis & Prevention*. 2017

9 FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*

10 Guide for the Planning, Design, and Operation of Pedestrian Facilities, AASHTO

11 Huang, H.F. and M.J. Cynecki. The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior. FHWA-RD-00-104. Federal Highway Administration. U.S. Department of Transportation, Washington, DC, 2001.

12 Candappa, N., K., S. N. Fotheringham, M.G. Lenne, and B. Corben. Raised Crosswalks on Entrance to the Roundabout -- A Case Study on Effectiveness of Treatment on Pedestrian Safety and Convenience. Traffic Injury Prevention, Vol. 15, No. 6, 2014, pp. 631-639.

13 The Department of Justice, United States Access Board's ADA Standards

14 FHWA's Designing Sidewalks and Trails for Access, Part 2, Best Practices Design Guide

15 The Department of Justice, United States Access Board's ADA Standards

16 FHWA's Designing Sidewalks and Trails for Access, Part 2, Best Practices Design Guide

17 *AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges*

18 https://www.dot.state.oh.us/drrc/Pages/default.aspx

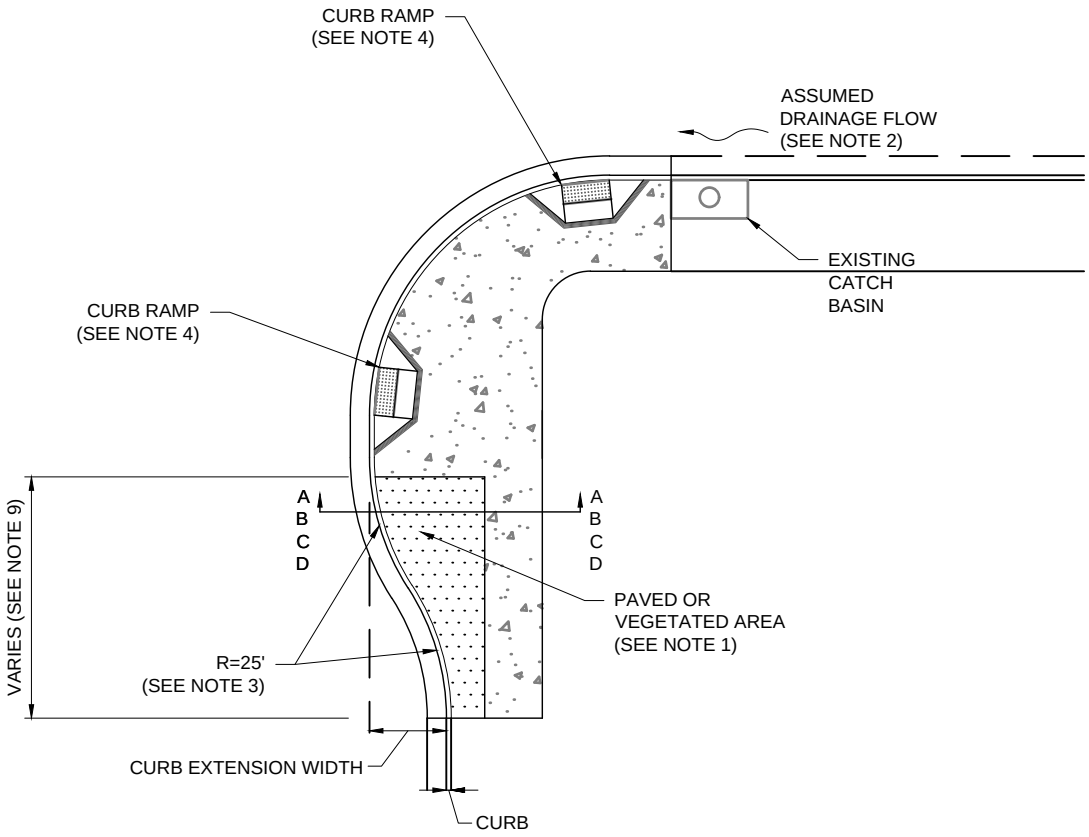
19 https://www.transportation.ohio.gov/wps/portal/gov/odot/working/publications/ada-design-resources

20 FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*

CURB EXTENSION DETAILS

DWG 4-1.1

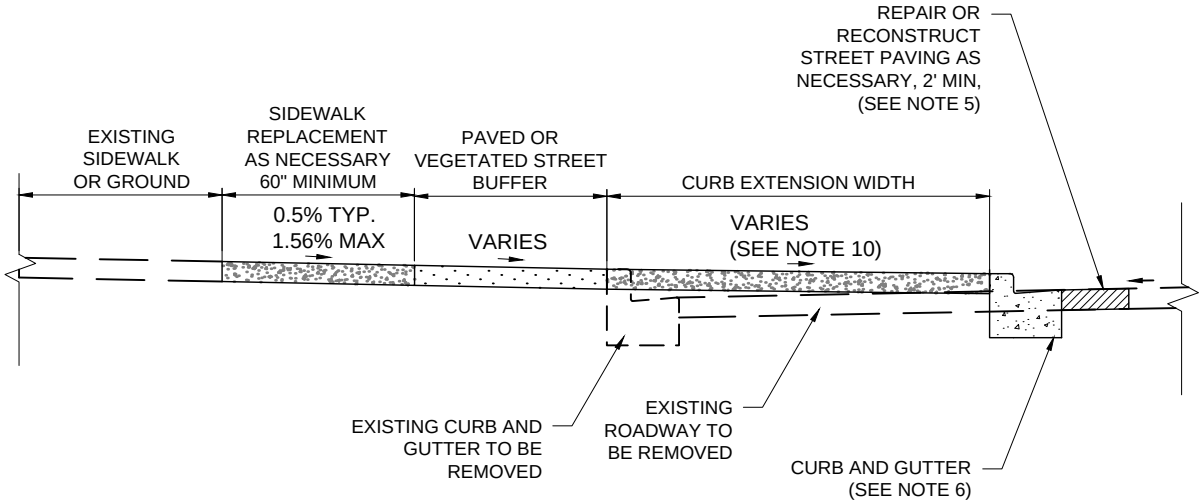
REFERENCE SECTIONS
4.5.4



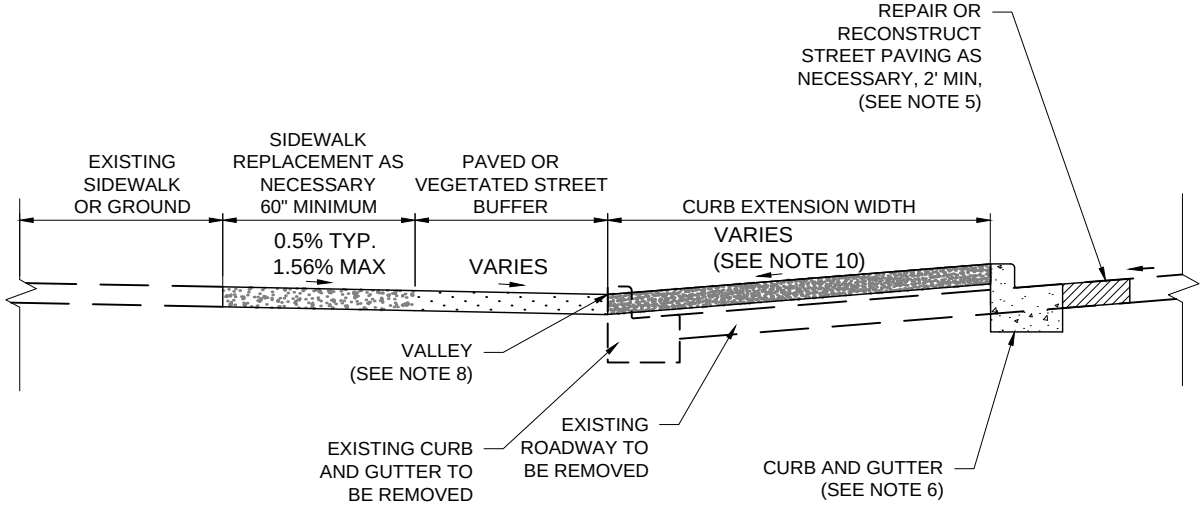
CURB EXTENSION DETAILS

DWG 4-1.2

REFERENCE SECTIONS
4.5.4


REPAIR OR RECONSTRUCT STREET PAVING AS NECESSARY, 2' MIN, (SEE NOTE 5)
EXISTING SIDEWALK OR GROUND
SIDEWALK REPLACEMENT AS NECESSARY 60" MINIMUM
PAVED OR VEGETATED STREET BUFFER
CURB EXTENSION WIDTH
0.5% TYP. 1.56% MAX
VARIES
VARIES (SEE NOTE 10)
EXISTING CURB AND GUTTER TO BE REMOVED
EXISTING ROADWAY TO BE REMOVED
CURB AND GUTTER (SEE NOTE 6)

SECTION A-A

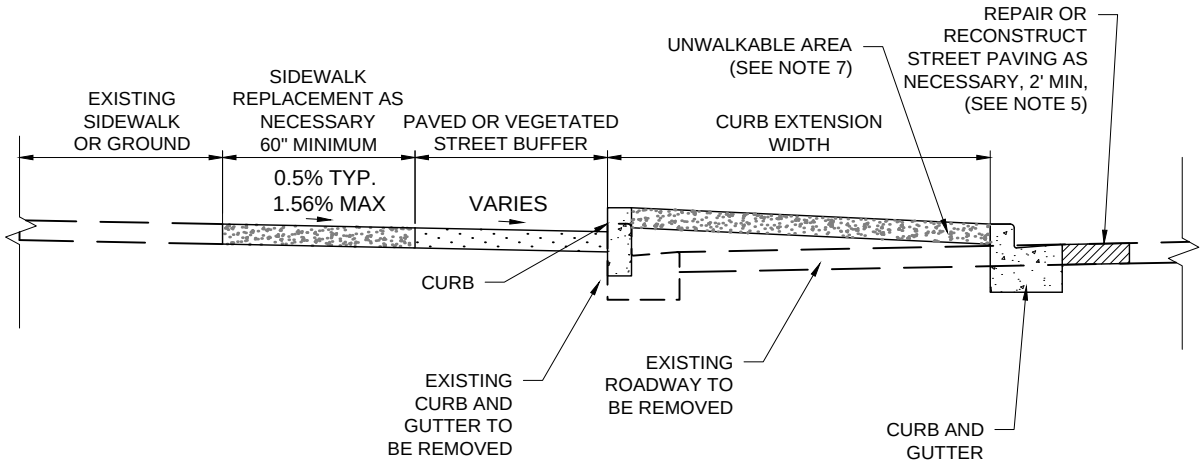

REPAIR OR RECONSTRUCT STREET PAVING AS NECESSARY, 2' MIN, (SEE NOTE 5)
EXISTING SIDEWALK OR GROUND
SIDEWALK REPLACEMENT AS NECESSARY 60" MINIMUM
PAVED OR VEGETATED STREET BUFFER
CURB EXTENSION WIDTH
0.5% TYP. 1.56% MAX
VARIES
VARIES (SEE NOTE 10)
VALLEY (SEE NOTE 8)
EXISTING CURB AND GUTTER TO BE REMOVED
EXISTING ROADWAY TO BE REMOVED
CURB AND GUTTER (SEE NOTE 6)

SECTION B-B

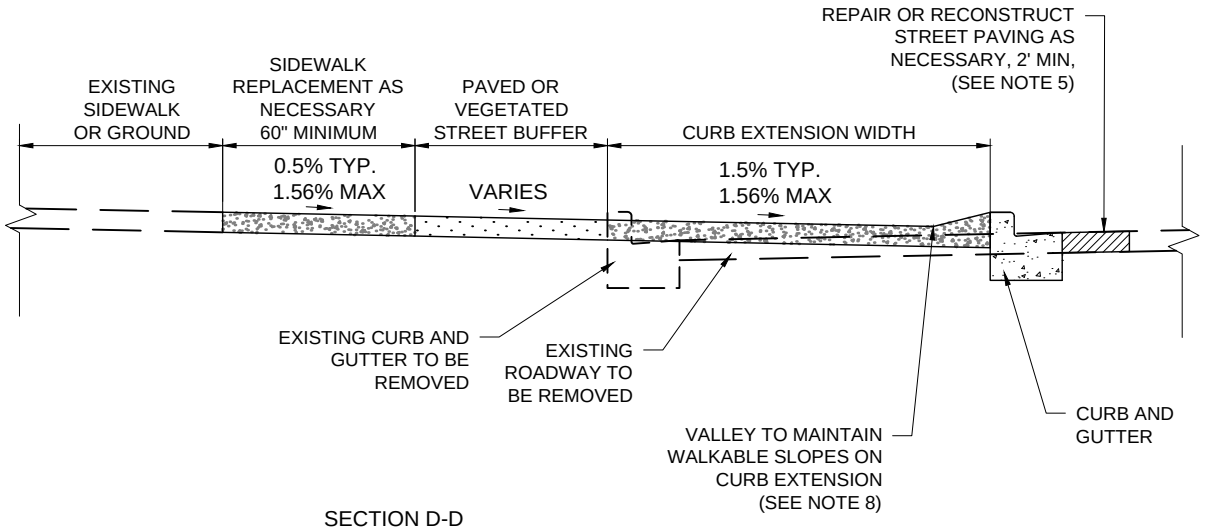
CURB EXTENSION DETAILS

DWG 4-1.3

REFERENCE SECTIONS
4.5.4


EXISTING SIDEWALK OR GROUND
SIDEWALK REPLACEMENT AS NECESSARY 60" MINIMUM
PAVED OR VEGETATED STREET BUFFER
CURB EXTENSION WIDTH
UNWALKABLE AREA (SEE NOTE 7)
REPAIR OR RECONSTRUCT STREET PAVING AS NECESSARY, 2' MIN, (SEE NOTE 5)
0.5% TYP.
1.56% MAX
VARIES
CURB
EXISTING CURB AND GUTTER TO BE REMOVED
EXISTING ROADWAY TO BE REMOVED
CURB AND GUTTER

SECTION C-C


EXISTING SIDEWALK OR GROUND
SIDEWALK REPLACEMENT AS NECESSARY 60" MINIMUM
PAVED OR VEGETATED STREET BUFFER
CURB EXTENSION WIDTH
REPAIR OR RECONSTRUCT STREET PAVING AS NECESSARY, 2' MIN, (SEE NOTE 5)
0.5% TYP.
1.56% MAX
VARIES
1.5% TYP.
1.56% MAX
EXISTING CURB AND GUTTER TO BE REMOVED
EXISTING ROADWAY TO BE REMOVED
VALLEY TO MAINTAIN WALKABLE SLOPES ON CURB EXTENSION (SEE NOTE 8)
CURB AND GUTTER

SECTION D-D

CURB EXTENSION DETAILS

DWG 4-1.4

REFERENCE SECTIONS
4.5.4

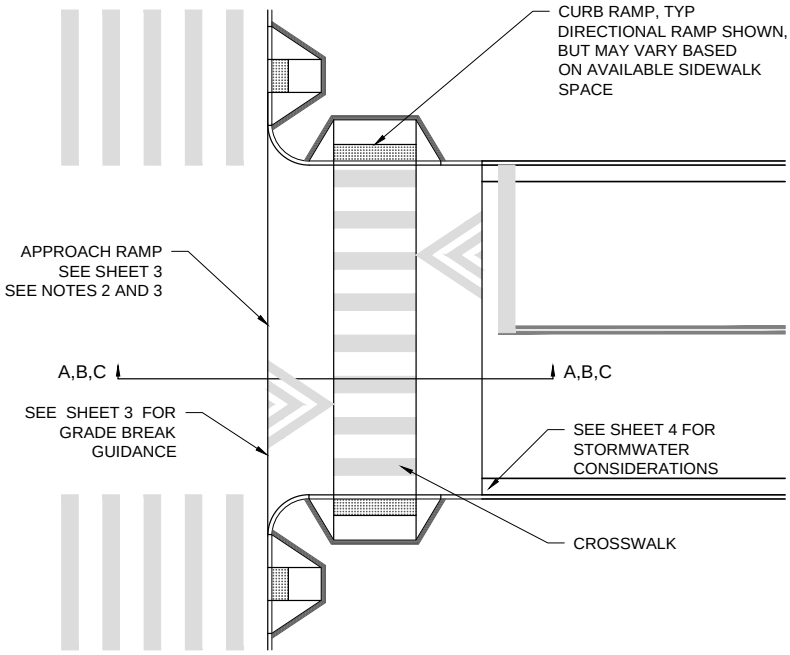
NOTES

1. AREA SHALL BE PAVED AND ADHERE TO ADA REQUIREMENTS WHEN WALKABLE SLOPES CAN BE ACHIEVED. WHEN WALKABLE SLOPES ARE UNATTAINABLE, TREATMENTS SHALL BE INSTALLED TO DISCOURAGE PEDESTRIANS FROM WALKING IN THE AREA. NON-WALKABLE ALTERNATIVES INCLUDE PLANTING BEDS OR VEGETATION. SEE CROSS SECTION A-A FOR DETAILS ON ALTERNATIVES. INLETS MAY ALSO BE PROVIDED WITHIN THE NON-WALKABLE AREAS..
2. WHERE POSITIVE DRAINAGE CANNOT BE MAINTAINED ALONG THE EXISTING AND PROPOSED CURB EXTENSION CURBLINE, ADDITIONAL DRAINAGE STRUCTURES SUCH AS CATCH BASINS OR TRENCH DRAINS WILL BE NECESSARY TO CONVEY STORMWATER.
3. A RADIUS OF 25' IS DESIRABLE TO ACCOMMODATE STREET SWEEPING AND PLOWING. A SMALLER RADIUS MAY BE CONSIDERED TO MAXIMIZE THE AREA OF THE CURB EXTENSION.
4. WHERE CURB EXTENSION HAS REVERSE SLOPE, RAMP SLOPE SHALL NOT BE LESS THAN 2% TOWARD THE STREET.
5. MODIFY THE EXISTING STREET PAVING AS NECESSARY TO RESTORE A SMOOTH TRANSITION AND STREET CROWN. MATCH PAVING MATERIALS AND THICKNESS. ENSURE POSITIVE DRAINAGE IS PROVIDED.
6. CURB HEIGHT MAY VARY BASED ON EXISTING OR PROPOSED STREET CROSS SLOPES. CURB HEIGHTS LESS THAN 4 INCHES REQUIRE APPROVAL FROM THE OFFICE OF ROADWAY ENGINEERING.
7. UNWALKABLE AREA MAY BE PAVED, VEGETATED, OR DESIGNED AS A STORMWATER BMP.
8. VALLEYS CREATED FROM REVERSE SLOPES SHALL BE DRAINED BACK TO THE CURB WHEN POSSIBLE TO AVOID PONDING ON THE CURB EXTENSION. WHERE A CROSS SLOPE OF 1.56% OR LESS IS NOT FEASIBLE, A NON-WALKABLE SURFACE MUST BE PROVIDED.
9. TRANSITION LENGTH SHALL VARY BASED ON THE WIDTH OF THE CURB EXTENSION AND THE CURB RADII USED FOR THE TRANSITION.
10. A WALKABLE ALTERNATIVE IS THE PREFERRED OPTION WHEN ADA COMPLIANT GRADES CAN BE ACHIEVED. FACTORS AFFECTING THE ABILITY TO PRODUCE WALKABLE GRADES INCLUDE ROADWAY CROSS SLOPE, EXISTING CURB HEIGHT, EXISTING GROUND OR SIDEWALK ELEVATION, AND THE WIDTH OF THE CURB EXTENSION. SLOPE SHOULD NOT EXCEED 1.56% TO BE CONSIDERED WALKABLE.

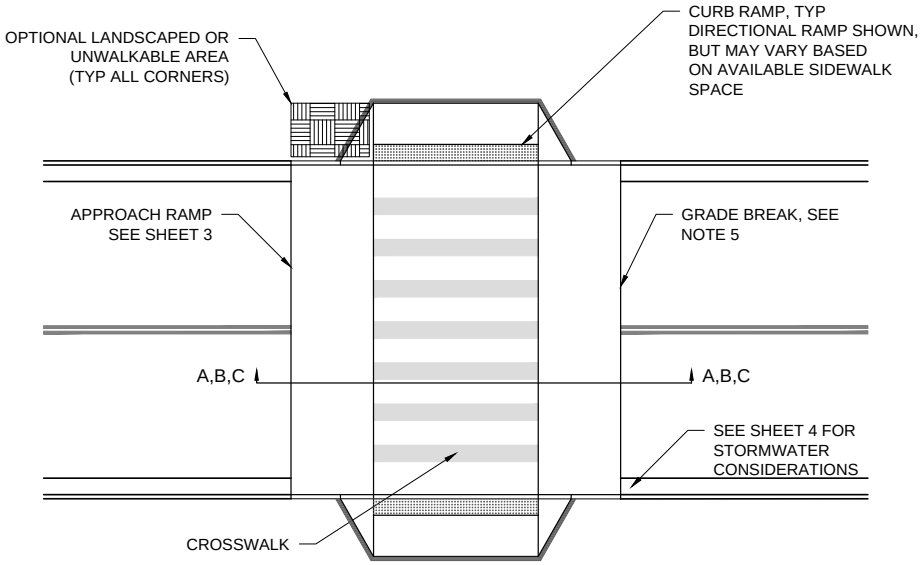
RAISED CROSSING DETAILS

DWG 4-2.1

REFERENCE SECTIONS
4.5.5



RAISED SIDE STREET

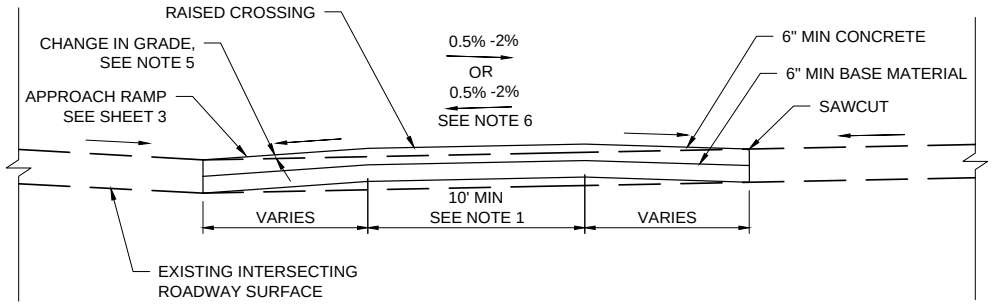


RAISED MID-BLOCK

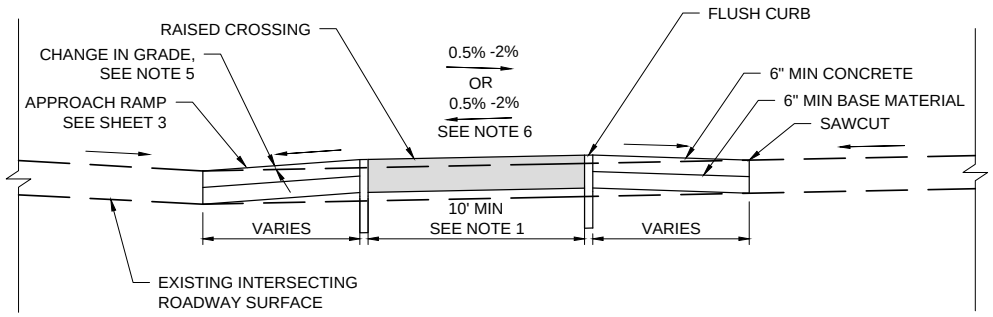
RAISED CROSSING DETAILS

DWG 4-2.2

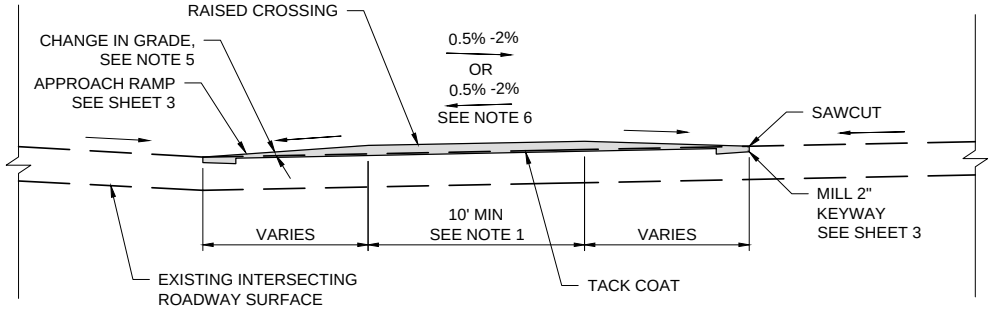
REFERENCE SECTIONS
4.5.5



SECTION A-A. CONCRETE RAISED CROSSING
N.T.S



SECTION B-B. CONCRETE RAMPS AND ASPHALT CROSSWALK
N.T.S



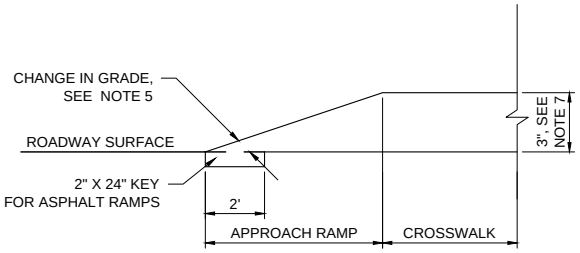
SECTION C-C. ASPHALT RAISED CROSSING
N.T.S

RAISED CROSSING SECTIONS

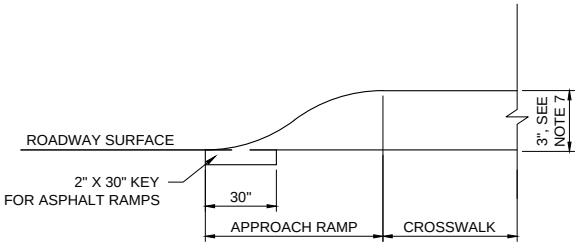
RAISED CROSSING DETAILS

DWG 4-2.3

REFERENCE SECTIONS
4.5.5



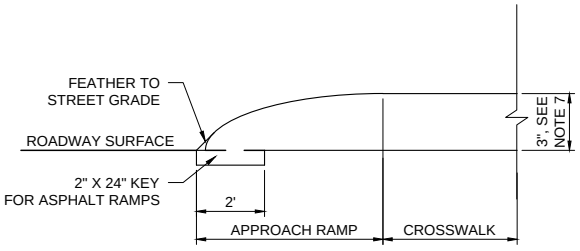
STRAIGHT APPROACH RAMP



SINUSOIDAL APPROACH RAMP

3" HEIGHT - SINUSOIDAL APPROACH RAMP

DISTANCE (FEET)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
FINISHED HEIGHT (INCHES)	0	0.05	0.20	0.44	0.75	1.11	1.50	1.89	2.25	2.56	2.80	2.95	3.00



PARABOLIC APPROACH RAMP

3" HEIGHT - PARABOLIC APPROACH RAMP

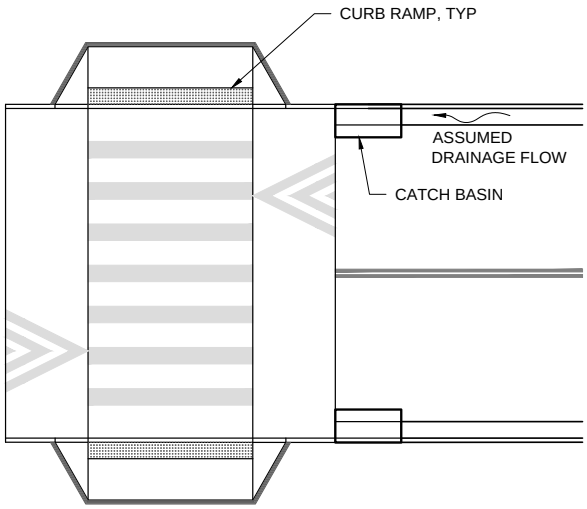
DISTANCE (FEET)	0	1.0	2.0	3.0	4.0	5.0	6.0
FINISHED HEIGHT (INCHES)	0	1.2	1.7	2.1	2.4	2.7	3.0

APPROACH RAMP PROFILES

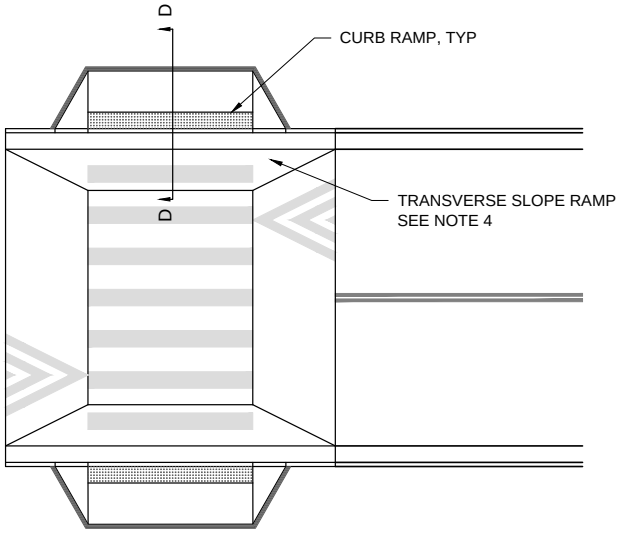
RAISED CROSSING DETAILS

DWG 4-2.4

REFERENCE SECTIONS
4.5.5



CASE A
NEW CATCH BASIN



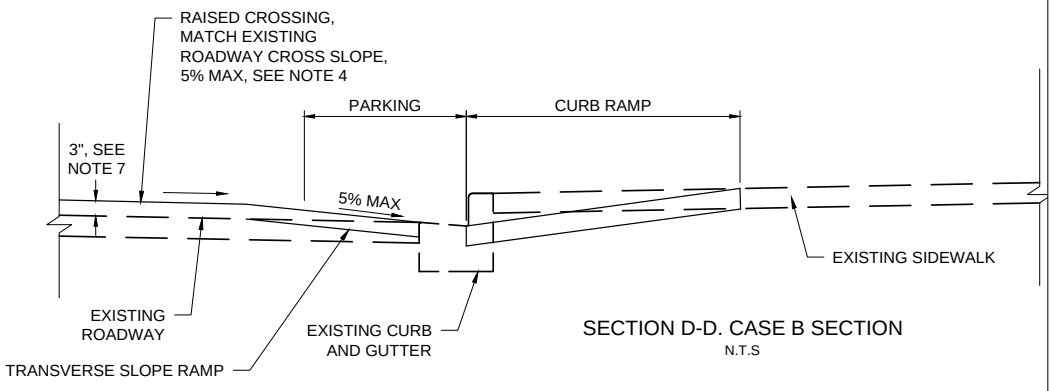
CASE B
EXISTING GUTTER FLOW

STORMWATER CONSIDERATIONS

RAISED CROSSING DETAILS

DWG 4-2.5

REFERENCE SECTIONS
4.5.5



SECTION D-D. CASE B SECTION
N.T.S

RAISED CROSSING DETAILS

DWG 4-2.6

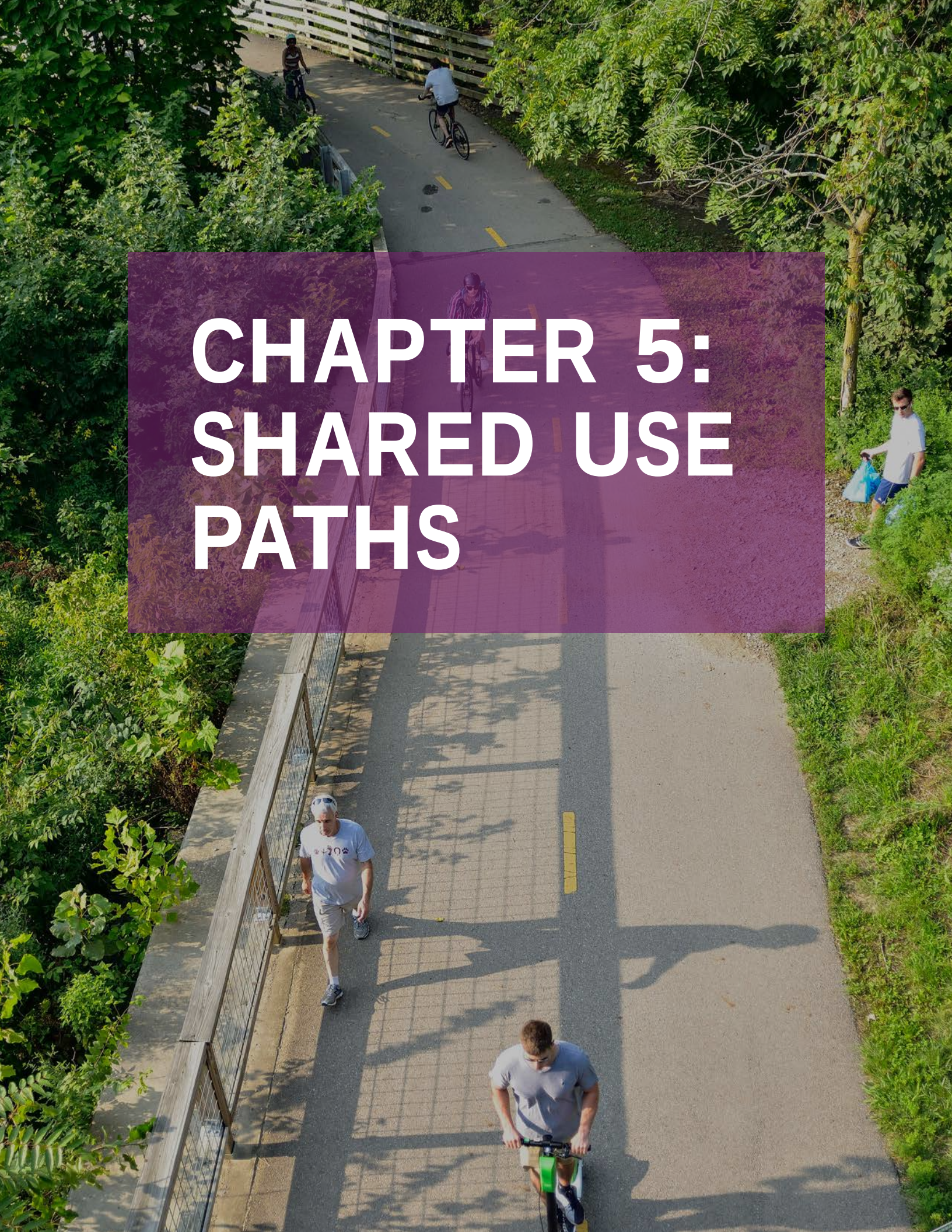
REFERENCE SECTIONS
4.5.5

GENERAL NOTES

WHERE POSITIVE DRAINAGE CANNOT BE ACHIEVED, INSTALL CATCH BASIN, AND CONNECT TO EXISTING STORMWATER CONVEYANCE SYSTEM. A RAISED CROSSING SET BACK FROM THE MAIN STREET MAY CREATE A NEW LOW POINT IN FRONT OF THE RAISED CROSSING. DRAINAGE AND CATCH BASIN PLACEMENT WILL NEED TO BE CONSIDERED.

NOTES

1. THE WIDTH OF THE TOP OF RAISED CROSSWALKS SHOULD MATCH THE WIDTH OF THE CONNECTING SIDEWALK, SHARED USE PATH, OR DESIRED CROSSWALK, BUT NOT LESS THAN 10' IN WIDTH.
2. BOTTOM EDGE OF RAISED CROSSING APPROACH RAMP TO BE ALIGNED WITH CURB LINE OF INTERSECTING STREET TO MINIMIZE IMPACTS TO SURFACE STORMWATER FLOWLINE.
3. MODIFICATIONS TO EXISTING STREET PAVING, MILL AND OVERLAY ASPHALT OR COMPLETELY RECONSTRUCT PAVING AS NECESSARY TO RESTORE A SMOOTH TRANSITION AND STREET CROWN, MATCH PAVING MATERIALS AND THICKNESS, AND WARP NEW GUTTER TO JOIN INVERT AT CATCH BASIN.
4. THE CASE B SECTION (SEE SHEET 4) IS APPROPRIATE ON ROADWAYS WITH PARKING. THE RAISED CROSSING SHOULD REACH FULL HEIGHT OUTSIDE OF ACTIVE TRAVEL LANES. THE CASE B SECTION MAY NOT BE APPROPRIATE ON ABNORMALLY CROWNED ROADWAYS, WHERE THE CROSS SLOPE EXCEEDS 3.3%.
5. CHANGE IN GRADE WILL VARY BASED ON THE TARGET SPEED FOR THE RAISED CROSSING. FOR RAISED CROSSINGS AT STOP CONTROLLED INTERSECTIONS OR MIDBLOCK WITH A TARGET SPEED <10 MPH, AN 8% CHANGE IN GRADE IS APPROPRIATE. FOR RAISED CROSSINGS WITH A TARGET SPEED ≥ 10 MPH, A 5% CHANGE IN GRADE SHOULD BE USED.
6. CROSSWALK CROSS SLOPES SHOULD BE NO GREATER THAN 2%, HOWEVER, AT LOCATIONS WITHOUT STOP CONTROL THE CROSS SLOPES MAY BE 5% MAX. AND AT MIDBLOCK LOCATIONS THE CROSS SLOPE MAY MATCH THE EXISTING STREET GRADE.
7. A 3" HEIGHT IS TYPICAL BUT A 4" - 5" HEIGHT MAY BE CONSIDERED FOR RESIDENTIAL STREETS.



CHAPTER 5: SHARED USE PATHS

Chapter 5: Shared Use Paths

This chapter provides guidance for shared use paths used by bicyclists and pedestrians, including those with disabilities, for transportation and recreation purposes. Shared use paths are physically separated from motor vehicle traffic by an open space or barrier.

5.1 General

Shared use paths are one of the preferred bikeway types for the Interested but Concerned Bicyclist design user profile (see Section 3.2.1) due to their separation from motor vehicle traffic.

Shared use paths should be thought of as a system of off-road transportation routes for pedestrians, bicyclists, and other non-motorized users that extends and complements the on-road bicycle network. Shared use paths are most commonly designed for two-way travel, and the guidance herein assumes a two-way facility is planned unless otherwise stated. The presence of a shared use path should not be used as a reason to preclude on-road bikeways where appropriate. A shared use path can supplement a network of separated bike lanes, on-road bike lanes, shared roadways, bicycle boulevards, and paved shoulders.

Shared use path design is similar to roadway design, following many of the same core design precepts but on a different scale and with typically lower design speeds.

5.1.1. Accessibility Requirements for Shared Use Paths

Shared use paths are used by pedestrians and must meet the accessibility requirements of the *Americans with Disabilities Act* (ADA). Paths in the public right-of-way that follow the roadway and function as sidewalks, commonly referred to as sidepaths, should be designed in accordance with the proposed *Public Rights of Way Accessibility Guidelines* (PROWAG). Shared use paths built in independent right-of-way should meet the draft accessibility guidelines in the Advance Notice of Proposed Rulemaking (ANPRM) on *Accessibility Guidelines for Shared Use Paths*.

Additional information on accessibility requirements for pedestrian facilities is described in Chapter 4.

The guidance in this section supplements the general elements of design discussed in Chapter 3 and provides additional details for designers working on shared use paths.

5.2 Shared Use Path Users

A wide range of users rely on shared use paths for a variety of trip purposes. Therefore, paths should be designed to accommodate a broad array of expected users and purposes. Some shared use paths are relatively short and connect single destinations such as a neighborhood to a school, park, retail center, or transit station. Some paths are longer and connect multiple destinations along a shared use path system. Some shared use paths are used primarily for recreational purposes while others are used primarily for transportation purposes such as commuting. The primary

differentiator in the design and maintenance of shared use paths for transportation purposes is the recognition that path users are dependent on path safety, accessibility, comfort, and convenience at all hours of the day and during all seasons of the year.

Path users may include but are not limited to:

- Pedestrians (including walkers, runners, people using wheelchairs, both non-motorized and motorized), people with baby strollers, people walking dogs, and others.
- Adult upright bicyclists, adult tricyclists, recumbent bicyclists, bicyclists pulling trailers, tandem bicyclists, and child bicyclists;
- Inline skaters, roller skaters, skateboarders, kick scooter users, and users of other micromobility devices.

5.2.1. Design User

As discussed in Section 3.2, shared use path design criteria should primarily be based on a person's physical and operating characteristics as a pedestrian or bicyclist (see Section 3.2.1), therefore different design users will be required to establish key design control values. For shared use paths these will generally be:

- **Geometric Design Controls** – path width should be based on the volume of pedestrians and bicyclists expected to use the path; however, design speed, acceleration and deceleration rates, and horizontal and vertical curvature, and clearances should be based on an adult bicyclist as they are typically the largest and fastest of all path users.
- **Sight Distance** - should be based on a recumbent or hand bicyclists as they typically have the lowest eye height of all path users.
- **Intersection Crossing Performance Criteria** - such as crossing time and acceleration should be based on pedestrians and child bicyclists as they are typically the slowest of all path users.
- **Queue Storage** - such as the width of crossing islands or other areas where bicyclist queuing length must be accounted for should be based on a bicyclist with a trailer as they are typically the longest path user.

5.3 General Design Considerations

5.3.1. Width and Clearances

Width

The appropriate paved width for a shared use path is dependent on the context, volume, and mix of users. When determining an appropriate shared use path width, it is also important to consider the natural behavior of people operating on paths. People traveling want the ability to have conversations with companions, thus they will walk and bicycle side-by-side regardless of the width provided (see Figure 5-1). Path widths less than 11 ft. in width do not provide space for people to travel side-by-side and be passed by other users approaching from the opposite direction without

increasing the potential for conflicts, so this should generally serve as the minimum width for shared use paths. An additional consideration for determining an appropriate path width is ensuring the inherent speed differential between wheeled users and people walking, and the volume of shared use path users, does not result in uncomfortable or unsafe conditions.

Figure 5-1: People Walking and Bicycling Naturally Prefer to Socialize by Operating Side-by-Side

Failure to account for normal human social behavior and the mix of operating speeds will result in user conflicts on shared use paths that operate at moderate to high volume thresholds. In some cases, the presence of frequent conflicts can result in some people avoiding the facility altogether. To mitigate safety and discomfort issues between wheeled users and people walking, it may be appropriate to consider paths wider than minimum widths.

Table 5-1: Shared Use Path Widths for Anticipated Peak Hour Volumes

Shared Use Path Operating Widths			
Minimum (ft)	SUPLOS "C" Peak Hour Volumes at Preferable Width	Constrained (ft)	SUPLOS "D" Peak Hour Volumes at Minimum Width
10 – 12	150 - 300	8	50
12 – 15	300 - 500	11	400
16 – ≥20	500 - ≥600	15	600

Table 5-1[1] shows minimum shared use path widths to achieve a Shared Use Path Level of Service (SUP LOS) of "C". Shared use path user volumes can be collected on an existing path, estimated using a similar path, or projected using land use and other demand characteristics present along the path. If the designer cannot collect or estimate the modal split values, a typical mode split of 60 percent bicyclists, 30 percent pedestrians, and 10 percent other wheeled users may be considered. Using a minimum SUP LOS of "C" helps to ensure the path has the minimum width necessary to meet current demand with a modest ability to carry some additional future capacity. At SUP LOS "D," the path will be at its functional capacity limit during peak periods which will result in significant service degradation for users due to crowding.

Table 5-1 should be used to inform the selection of a shared use path width to serve the desired volume, user mix and operational conditions for the path. Regionally significant paths serving a wide range of users, with faster bicyclists using the facility for transportation and recreation, may

benefit from the ability to operate on wider width shared use paths.

As path widths begin to exceed 15 ft. in width, it may be desirable to separate pedestrians from bicyclists to minimize speed differential between pedestrians and wheeled users in lieu of providing a wider shared use path.

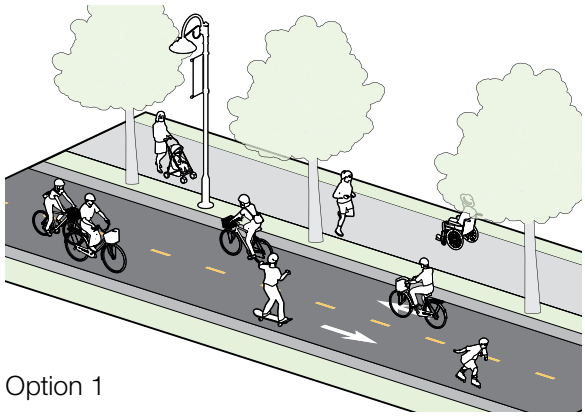
The FHWA Shared Use Path Level of Service Calculator can help designers understand potential volume thresholds where passing movements between bicyclists and pedestrians will limit the effectiveness of a shared use path. To improve the comfort and safety of bicyclists and pedestrians, and to improve the efficiency of the shared use path for bicycle travel, separation of bicyclists and pedestrians should be considered when:

- Level of Service is projected to be at or below level "C"
- Pedestrians can reasonably be anticipated to be 30 percent or more of the volume
- Higher volumes of children, seniors, or individuals with disabilities are likely to be present
- Where faster bicycle speed is desired to serve regionally significant bicycle travel

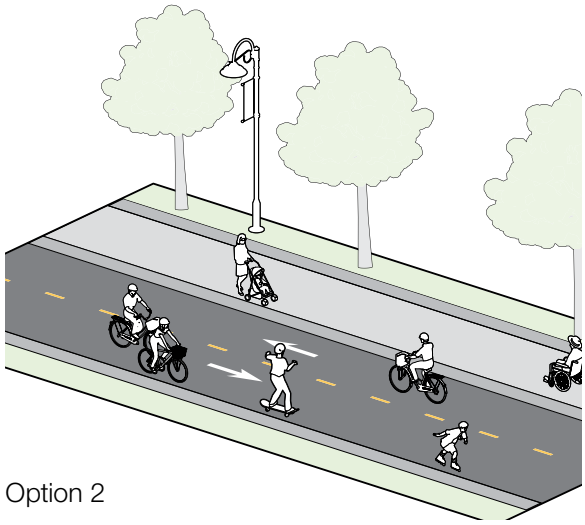
Where it is determined to separate bicyclists and other higher-speed wheeled users from pedestrians (including people walking or using wheelchairs or other assistive devices) there are three strategies which can be considered (see Figure 5-2):

1. A wide path can be provided which separates users using pavement markings
2. A wide path can be provided which separates users with a traversable surface delineation
3. Separate bikeways and walkways can be used which are physical separated from each other

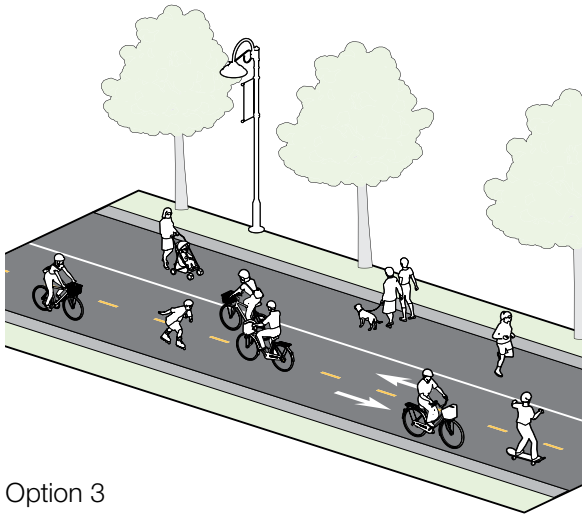
Figure 5-2: Potential Options for Separation of Shared Use Paths



Option 1



Option 2



Option 3

Horizontal and Vertical Clearances

A graded shoulder width of at least 5 ft. with a maximum cross slope of 6:1 should be provided on each side of a shared use path. Shy distances from obstructions such as bushes, large rocks, bridge piers, abutments, and poles should be provided per Section 3.6.2. See Figure 5-3 for a typical cross-section of a shared use path.

Where paths are adjacent to parallel bodies of water or downward slopes of 3:1 or steeper, a wider separation should be considered. A 5 ft. separation from the edge of path pavement to the top of the slope is desirable. Depending on the height of the embankment and condition at the bottom, a physical barrier, such as dense shrubbery, railing or fencing may be appropriate. Where a recovery area (distance between the edge of the path pavement and the top of the slope) is less than 5 ft., physical barriers are recommended in the following situations (see Figure 5-3):

- Slope 3:1 or greater, with a drop of 6 ft. or greater;
- Slope 3:1 or greater, adjacent to a parallel body of water or other substantial object;
- Slope 2:1 or greater, with a drop of 4 ft. or greater;
- Slope 1:1 or greater, with a drop of 1 ft. or greater.

The barrier should begin prior to, and extend beyond, the area of need similar to the implementation of guardrail with shy spaces per Section 3.6.2. The ends of the barrier should be flared away from the path edge, particularly if constrained dimensions are used.

It is not desirable to place the pathway in a narrow corridor between two fences for long distances, as this creates personal security issues, prevents users who need help from being seen, prevents path users from leaving the path in an emergency, and impedes emergency response.

Additional information on horizontal and vertical shy space is provided in Section 3.6.2.

In addition to shy spaces for path user comfort and operations, additional horizontal clearances may be needed to accommodate bicyclist sight lines and stopping sight distances in areas of horizontal alignments. Figure 5-4 and Table 5-2 illustrate and identify the minimum lateral clearances need to provide sight lines through horizontal alignments. On narrower paths, bicyclists tend to ride near the middle of the path. Lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for path users travelling in opposite directions around the curve.

Figure 5-3: Typical Shared Use Path Cross-Sections (left), Steep Slope Edge Treatment (right)

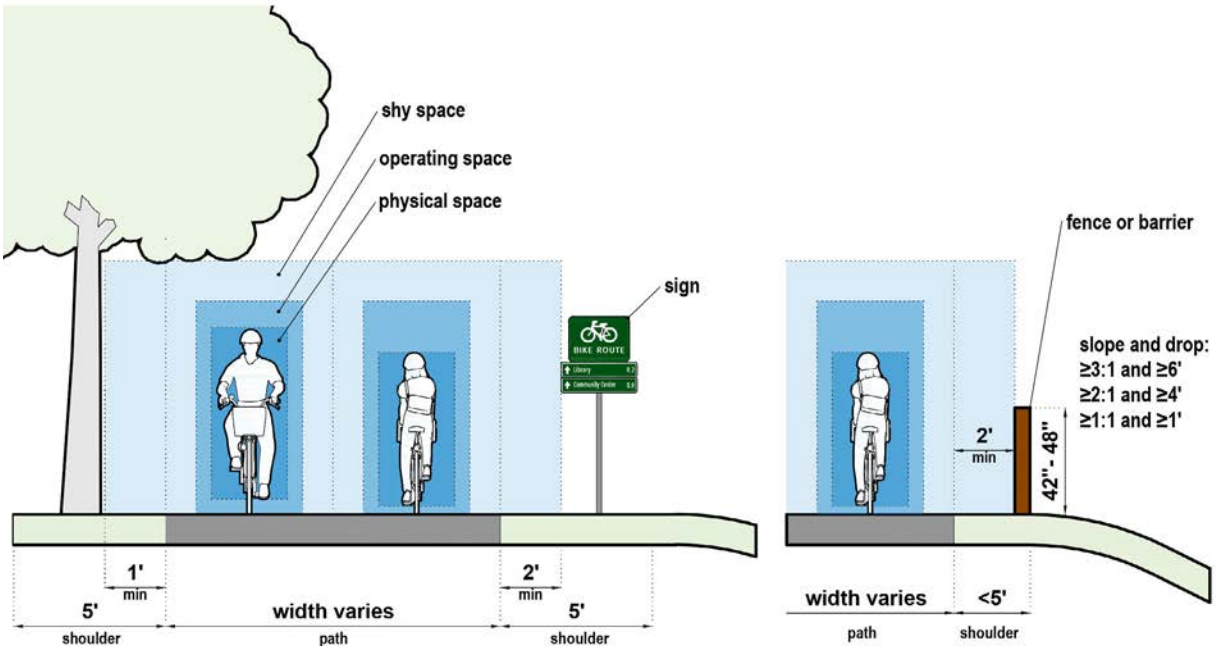


Figure 5-4: Horizontal Sightline Offset for Adjacent Path Objects

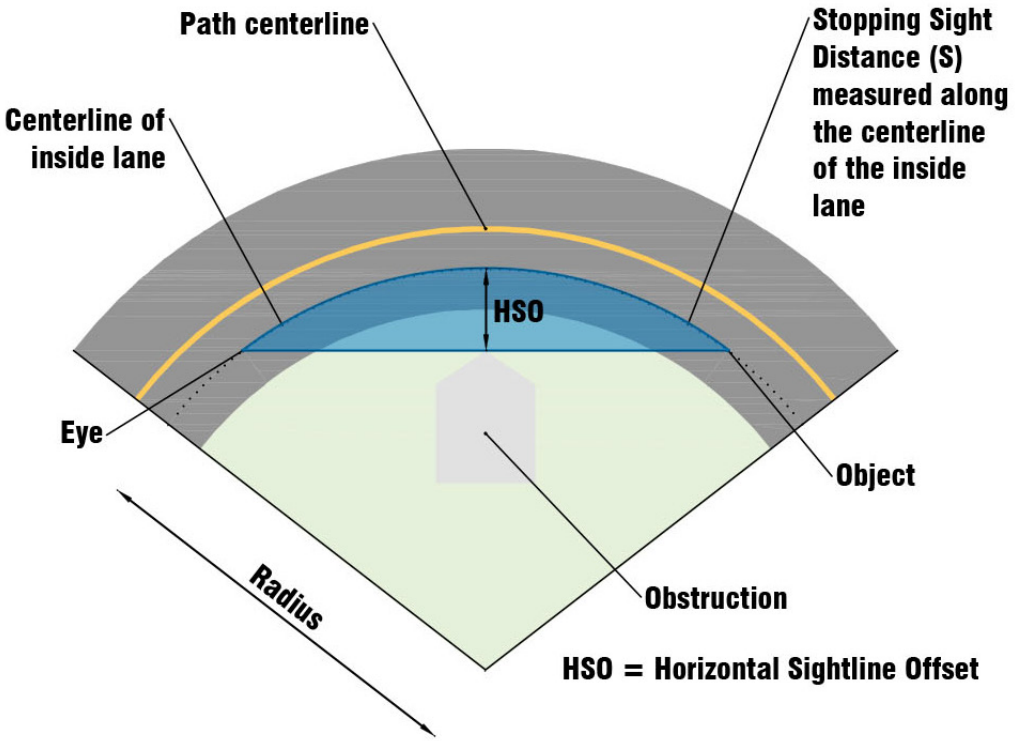


Table 5-2: Minimum Lateral Clearance for Horizontal Curves

Minimum Lateral Clearance (Horizontal Sightline Offset or HSO) for Horizontal Curves (ft)														
R (ft)	S = Stopping Sight Distance (ft)													
	40	60	80	100	120	140	160	180	200	220	240	260	280	300
25	7.6	15.9												
50	3.9	8.7	15.2	23.0	31.9	41.5								
75	2.7	5.9	10.4	16.1	22.8	30.4	38.8	47.8	57.4	67.2				
95		4.7	8.3	12.9	18.3	24.7	31.8	39.5	48.0	56.9	66.3	75.9	85.8	
125		3.6	6.3	9.9	14.1	19.1	24.7	31.0	37.9	45.4	53.3	61.7	70.6	79.7
155		2.9	5.1	8.0	11.5	15.5	20.2	25.4	31.2	37.4	44.2	51.4	59.1	67.1
175		2.6	4.6	7.1	10.2	13.8	18.0	22.6	27.8	33.5	39.6	46.1	53.1	60.5
200			4.0	6.2	8.9	12.1	15.8	19.9	24.5	29.5	34.9	40.8	47.0	53.7
225			3.5	5.5	8.0	10.8	14.1	17.8	21.9	26.4	31.3	36.5	42.2	48.2
250			3.2	5.0	7.2	9.7	12.7	16.0	19.7	23.8	28.3	33.1	38.2	43.7
275			2.9	4.5	6.5	8.9	11.6	14.6	18.0	21.7	25.8	30.2	34.9	39.9
300			2.7	4.2	6.0	8.1	10.6	13.4	16.5	19.9	23.7	27.7	32.1	36.7
350				3.6	5.1	7.0	9.1	11.5	14.2	17.1	20.4	23.9	27.6	31.7
390				3.2	4.6	6.3	8.2	10.3	12.8	15.4	18.3	21.5	24.9	28.5
500				2.5	3.6	4.9	6.4	8.1	10.0	12.1	14.3	16.8	19.5	22.3
565					3.2	4.3	5.7	7.2	8.8	10.7	12.7	14.9	17.3	19.8
600					3.0	4.1	5.3	6.7	8.3	10.1	12.0	14.0	16.3	18.7
700					2.6	3.5	4.6	5.8	7.1	8.6	10.3	12.0	14.0	16.0
800						3.1	4.0	5.1	6.2	7.6	9.0	10.5	12.2	14.0
900						2.7	3.6	4.5	5.6	6.7	8.0	9.4	10.9	12.5
1000							3.2	4.0	5.0	6.0	7.2	8.4	9.8	11.2

5.3.2. Sidepaths

Sidepaths are a type of shared use path that are located parallel to a roadway and may be considered in addition to on-road bikeways. The primary distinction between sidepaths and shared use paths on independent alignments is their intersection context. Side path intersections occur within the functional area of a roadway-roadway intersection (see Section 6.5.2). For shared use paths on independent alignments, shared use path crossings may occur at mid-block roadway locations (see Section 5.6.3) or at roadway-roadway intersections. The geometric and operational design of side path intersections closely follows the best practices for separated bike lanes (see Chapter 6). However, when designing sidepaths, the designer should use this chapter for all other elements of design including path width and other supportive design elements, as separated bike lanes are not designed to accommodate pedestrians.

While it is generally preferable to select path alignments in independent rights-of-way, there are situations where existing roads provide the only corridors available and may be considered where one or more of the following conditions exist:

- The adjacent roadway has relatively high-volume and high-speed motor vehicle traffic that might discourage many bicyclists from riding on the roadway, potentially increasing sidewalk riding, and there are no practical alternatives for either improving the roadway or accommodating bicyclists on nearby parallel streets.
- The side path is used for a short distance to provide continuity between sections of path in independent rights-of-way, or to connect local streets that are used as bicycle routes.
- The side path can be terminated at each end onto streets that accommodate bicyclists, onto another path, or in a location that is otherwise bicycle compatible.

A wide separation should be provided between a sidepath and the adjacent roadway where possible. The minimum recommended distance between a path and the roadway curb or edge of travelled way (where there is no curb) is 5 ft., though this can be reduced to 2 ft. in constrained areas. Where a paved shoulder is present, the separation distance begins at the outside edge of shoulder.

5.3.3. Design Speed

As discussed in Section 3.3, a design speed is used to determine various geometric features of a shared use path. In most situations, shared use paths should be designed for a speed that is comfortable and appropriate for the design user profile in a given context. There is no single design speed recommended for all shared use paths, and design speeds may change along portions of shared use paths as they travel through different contexts. This is especially the case for longer paths that transition between suburban/rural settings and urban settings where contextual conditions and demand expectations are different. Table 5-3 provides recommended shared use path design speeds based on context.

Table 5-3: Shared Use Path Design Speed by Context

Design Speed	Shared Use Path Context	Description
12 mph	Unpaved path surfaces	On unpaved path surfaces, bicyclists tend to travel slower to compensate for reduced braking ability, so a lower design speed (12 mph) may be used.
15mph	Paved, high volumes with diverse users	For most shared use paths with higher volumes of users in relatively flat areas, a design speed of 15 mph is generally appropriate due to the mixed-use operation with pedestrians on the facility.
18-30mph	Paved, low volume of users, especially pedestrians	For shared use paths with lower volumes of users, where pedestrian volumes are low (less than 30 percent), where the primary purpose of the shared use path is to provide a higher speed bicycling opportunity between destinations, or on wider paths where bicycles are provided separate spaces from pedestrians, a design speed of 18 – 30 mph may be appropriate.
18-30mph	Paved, rolling terrain	On shared use paths with rolling terrain and sustained steeper grades (greater than 5 percent), the appropriate design speed should be selected based on the anticipated travel speeds of bicyclists going downhill; however, design speed should generally not exceed 30 mph.

While some bicyclists - as well as emerging technologies such as electric assist bicycles and motorized micromobility devices - can travel faster than the noted design speeds, designing to accommodate the fastest possible speed is often not appropriate in many contexts. However, designers should understand that due to the linear nature of shared use paths, some users may travel faster than the desired operational speeds.

The design speed should not change frequently or have extreme variations. Transitions between speed zones should be included and may include signage (see Section 5.7.1) or other strategies for reducing bicyclist speeds (see Section 5.6.2) to inform bicyclists that slower speeds are required and alert them to potential conflicts. Any change in design speed should be identified in the project documents explaining the reason for changing the design speed and specific elements that were considered as part of the decision making process.

5.3.4. Horizontal Alignment

The minimum radius of horizontal curvature for bicyclists can be calculated using two different methods. One method uses “lean angle”, and the other method uses superelevation and coefficient of friction. In general, the lean angle method should be used in design. Table 5-4 shows minimum radii of curvature for a paved path using a 20-degree lean angle. See the AASHTO *Guide for the Development of Bicycle Facilities* for information on calculating the minimum radius based on superelevation and coefficient of friction.

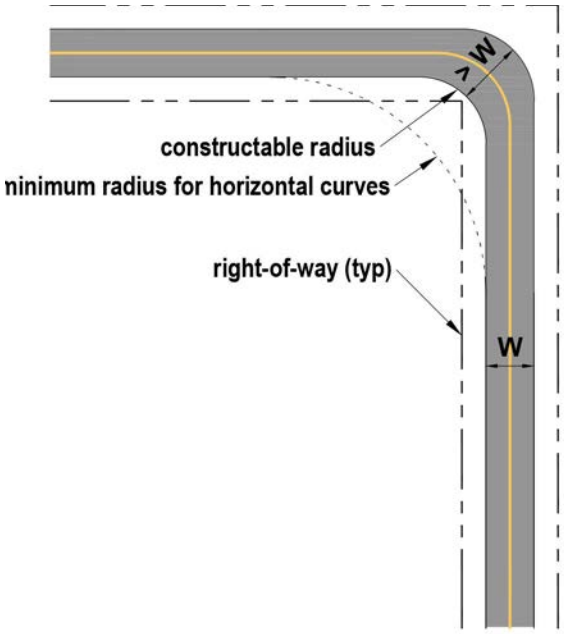
Tapers can also be used to change path horizontal direction. Tapers should generally occur gradually, with a minimum length discussed in Section 3.6.3. When using tapers to change direction, designers should consider adding a radius to the beginning and end of the taper to mimic a bicyclist’s natural path.

In retrofit or constrained conditions where the appropriate horizontal curve radius cannot be achieved due to physical or right-of-way constraints, and especially where the shared use path is a 90-degree or larger corner, designers should consider widening the path at the curve as shown in Figure 5-5 to provide more space to maneuver through the curve.

Table 5-4: Minimum Radii for Horizontal Curve on Paved Shared Use Path at a 20-degree Lean Angle

US Customary	
Design Speed (mph)	Minimum Radius (ft)
12	27
14	36
16	47
18	60
20	74
25	115
30	166

Figure 5-5: Figure 55: Shared Use Path Horizontal Alignment in Constrained Areas



5.3.5. Cross Slope

For the reasons mentioned in Section 3.7.3, a 1.56 percent cross slope is recommended for the design of shared use paths to help ensure the 2 percent maximum accessible cross slope is constructable. A cross slope of 1.56 percent also provides enough slope to convey surface drainage in most situations. A cross-section that provides a center crown with no more than 1.56 percent slope in each direction may also be used, but may be more difficult to construct particularly on narrower shared use paths.

Because this guide recommends a relatively flat cross slope, and because horizontal curvature can be based on a 20-degree lean angle, superelevation for horizontal curvature is not needed. Since superelevation is not needed for horizontal curvature, cross slopes can follow the direction of the existing terrain. This practice enables the designer to better accommodate surface drainage and lessen construction impacts.

In situations where a path is intended for bicycle use only and does not need to meet accessibility guidelines, (e.g., pedestrians are accommodated on a separate sidewalk or path), cross slopes between 2 and 8 percent may be used. If cross slopes steeper than 2 percent are needed, they

should be sloped to the inside of horizontal curves regardless of drainage conditions. In these situations, the path should follow design guidance found in Section 6.3.7 Separated Bicycle Lanes. In any situation, ADA paths and paths with lower cross slopes are generally more comfortable for bicyclists of all types.

Cross slopes should be transitioned to connect to existing slopes, or to adjust to a reversal of predominant terrain slope or drainage, or to a horizontal curve in some situations. Cross slope transitions should be gradual and comfortable for the path user. A minimum transition length of 5 ft. for each 1 percent change in cross slope should be used.

5.3.6. Vertical Alignment

The maximum grade of a shared use path contained within the roadway right-of-way shall not exceed the general grade established for the adjacent roadway. Consistent with the U.S. Access Board's *Supplemental Notice of Proposed Rulemaking* (SNPRM) on Shared Use Paths, where the shared use path is not contained within the roadway right-of-way, the grade should be kept to a minimum and the maximum grade of the shared use path should not exceed 5 percent.

If the path is at or approaching 5 percent for a significant length (1000 ft. or more), this sustained grade would be quite noticeable for a bicyclists or wheelchair user and maximum slopes of 3 to 4 percent should be considered. Alternately, or in addition to a lower sustained grade, pull-outs could be provided at strategic locations for users to get out of the travel path to pause or rest.

Where physical constrains (existing terrain or infrastructure, notable natural features, etc.) or regulatory constraints (endangers species, the environment, etc.) prevent full compliance with the 5 percent maximum grades, additional mitigations should be considered. Options to mitigate excessive grades on shared use paths include the following:

- Use higher design speeds for horizontal and vertical alignments, stopping sight distance, and other geometric features.
- When steep grades occur over a long distance, consider an additional 4 to 6 ft. of width to permit slower bicyclists to dismount and walk uphill, and to provide more maneuvering space for faster downhill bicyclists.
- Install the Hill Warning (W7-5) sign for bicyclists and advisory speed plaque in conditions where the steep grade is unexpected and not visible.
- Exceed minimum shy distances, add recovery areas and/or protective barriers (see Section 3.6.2).
- If other designs are not practicable, for shared use paths use a series of switchbacks to traverse the grade. If this is done, an extra 4 to 6 ft. of path width should be considered to provide maneuvering space and allow faster climbing bicyclists to pass slower bicyclists. Where switchbacks must make abrupt 180-degree turns, additional space should be provided in these turning areas to allow bicyclists to swing wide to navigate the turns.
- Provide resting intervals with flatter grades to permit users to stop periodically and rest.

- Consider the provision of accessible pedestrian handrails located outside of the bicyclist operating space but within accessible reach of the firm stable path surface.

See Section 5.3.8 for vertical crest curve guidance based on sight distances.

5.3.7. Drainage

Minimum pavement longitudinal grades of 0.5 percent and cross slopes of 1 percent usually provides adequate drainage conveyance. Providing a cross slope in one direction instead of crowning is preferred and usually simplifies drainage and path construction. An even surface is essential to prevent water ponding and ice formation. On unpaved paths, particular attention should be paid to drainage to avoid erosion and ponding.

Depending on site conditions, shared use paths with cross slopes in the direction of the existing terrain will typically provide sheet flow of surface runoff and avoid the need for channelizing flow in ditches, cross culverts, and closed pipe systems. Low points on the bikeway should be kept at a minimum or adequate drainage should be provided to keep stormwater from ponding within the operating space of bicyclists.

Where a shared use path is constructed on the side of a slope that has considerable runoff or other conditions that result in relatively high runoff, a ditch should be placed on the uphill side to intercept the slope's drainage. Ditches adjacent to the shared use path should be designed with bicycle safety in mind, per the guidance in Sections 5.3.1. Where needed, catch basins and manholes should be located outside of the shared use path and shy spaces (see Section 3.6.2).

To prevent erosion in the area adjacent to the shared use path, consideration should be given to preserving a hardy, natural ground cover. Shy distances and shoulder/buffer widths should be maintained adjacent to steep slopes or other potential hazards. In addition, shared use path design should meet applicable stormwater management regulations.

Additional guidance for drainage can be found in Chapter 3 and in the L&D Manual Volume 2.

5.3.8. Stopping Sight Distance

To provide path users with opportunities to see and react to unexpected conditions, shared use paths should be designed with adequate stopping sight distances.

For a crest vertical curve, the height of eye is assumed to be 3.83 ft. for a recumbent bicyclist and the object height is assumed to be 0 inches to recognize that impediments to bicycle travel exists at pavement level. Table 5-5 can be used to select the minimum length of vertical curve needed to provide minimum stopping sight distances at various speeds on crest vertical curves.

See Section 5.3.1 for sight distances related to horizontal clearances, Section 3.5.1 for additional discussion of stopping sight distance, and Section 3.5.2 for intersection sight distance cases.

Table 5-5: Minimum Length of Crest Vertical Curve (ft) Based on Stopping Sight Distance

Stopping Sight Distance														
%	40	60	80	100	120	140	160	180	200	220	240	260	280	300
2									17	57	97	137	177	217
3						25	65	105	145	185	226	265	307	352
4				8.5	48.5	88.5	128.5	169	209	253	301	353	409	470
5			7	47	87	128	167	211	261	316	376	441	512	587
6			32	72	113	154	201	254	313	379	451	530	614	705
7		11	51	91	132	179	234	296	366	442	526	618	716	822
8		24	64	104	150	205	267	338	418	505	602	706	819	940
9		35	75	117	169	230	301	381	470	569	677	794	921	1057
10	3	43	84	131	188	256	334	423	522	632	752	883	1023	1175
11	10	50	92	144	207	281	368	465	574	695	827	971	1126	1292
12	16	56	100	157	226	307	401	508	627	758	902	1059	1228	1410
13	21	61	109	170	244	333	434	550	679	821	978	1147	1331	1527
14	25	66	117	183	263	358	468	592	731	885	1053	1236	1433	1645
15	29	70	125	196	282	384	501	634	783	948	1128	1324	1535	1762
16	32	75	134	209	301	409	535	677	836	1011	1203	1412	1638	1880
17	35	80	142	222	320	435	568	719	888	1074	1278	1500	1740	1997
18	38	85	150	235	338	461	602	761	940	1137	1354	1589	1842	2115
19	40	89	159	248	357	486	635	804	992	1201	1429	1677	1945	2232
20	42	94	167	261	376	512	668	846	1044	1264	1504	1765	2047	2350

5.3.9. Surface Structure

Shared use paths should be stable, firm and slip resistant and be accessible to and usable by individuals with disabilities. All-weather concrete, asphalt pavement, or permeable pavement surfaces are preferred over surfaces of crushed aggregate, sand, clay, or stabilized earth. On shared use paths, loads should be substantially less than on roadways. However, to prevent pavement damage, which can contribute to bicycle crashes, shared use paths should be designed to sustain wheel loads of occasional emergency, patrol, maintenance, and other motor vehicles that are permitted to use or cross the path.

It is important to maintain a smooth riding surface on shared use paths. Vertical alignment shall be generally planar within the shared use path including curb ramp runs, turning spaces, and gutter areas. See Chapter 4 for additional information on accessibility requirements for facilities with pedestrian activity and Chapter 12 for maintenance considerations.

5.4 Bridges and Underpasses for Paths

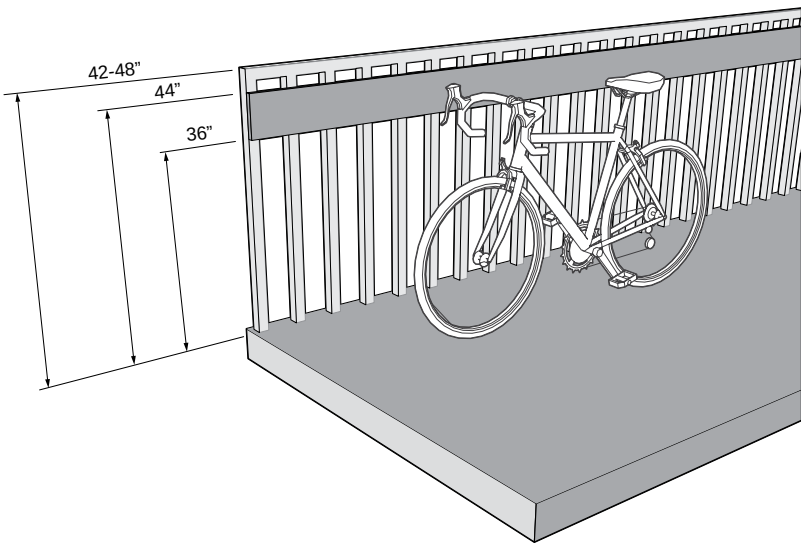
The clear width of a shared use path on a bridge or in an underpass should account for the necessary operating space and shy spaces. The paved width of the path (barrier-to-barrier or wall-to-wall width) should allow 2 ft. of shy space on each side of the shared use path. Under constrained conditions the shy space may be reduced to 1 ft. (see Section 3.6.2).

Railings, barriers, and fencing are common components of bridges and bridge approaches. On bridges, these elements can serve a variety of purposes, as crashworthy barriers for vehicles, as pedestrian railings, as "anti-throw" screens, to provide a vertical element adjacent to a drop-off, and as an aesthetic component of the bridge. Protective railings, fences, or barriers on either side of a shared use path on a stand-alone structure should be a minimum of 42 inches high. There are some locations where a 48 inches high railing should be considered in order to prevent bicyclists from falling over the railing during a crash. This includes bridges or bridge approaches where high-speed, steep angle impacts between a bicyclist and a railing may occur, such as at a curve at the foot of a long descending grade where the curve radius is less than appropriate for the design speed or anticipated speed. If a fence is provided, higher railings may not be needed.

Openings between horizontal or vertical members on railings should be small enough that a 6 inch sphere cannot pass through them in the lower 27 inches. For the portion of railing that is higher than 27 inches, openings may be spaced such that an 8 inch sphere cannot pass through them. This is done to prevent children from falling through the openings. Where a bicyclist's handlebar may come into contact with a railing or other barrier, a smooth wide rubrail may be installed at a height of 36 inches to 44 inches to reduce the likelihood that bicyclist's handlebar will be caught by the railing (see Figure 5-6). The design of railings and rubrail should be coordinated with the bridge engineer and architect (if relevant) to address the functional design, pedestrian accessibility, and desired aesthetics.

The structural design of shared use path bridges should be designed in accordance with the ODOT *Bridge Design Manual* and the AASHTO *LRFD Bridge Design Specifications for Design of Pedestrian Bridges.*

Figure 5-6: Example Bridge Railing with Bicycle Rubrail



5.5 Path Amenities

Shared use path entrances serve as gateways and typically offer a variety of amenities to accommodate shared use path users transitioning from the road to the path system. The following are amenities that may be considered as reasonable parts of a bikeway project:

- Informational kiosks, signs and bulletin boards – These can include helpful information such as the name of the shared use path, operating hours, "you are here" maps, contact information to report problems, emergency response information such as contact information, and shared use path rules and regulations. These should meet accessibility requirements for position, height and legibility of signs.
- Bicycle parking – Bicycle parking is less important at entrances of paved shared use paths in urban areas because most people accessing the shared use path are using their bicycles. Bicycle parking is more important at rest areas with bathrooms and at locations that connect to parks, playgrounds, retail areas, restaurants and other similar locations where shared use path users are likely to need to leave their bicycles for a period of time. Bicycle racks are also important at spur hiking trails that may be accessed by people arriving by bicycle. See Chapter 6 for further details regarding bicycle parking.
- Vehicular parking – Most shared use path entrances do not provide off-street parking for motor vehicles, particularly where parking is located nearby, or where many users live near the shared use path and are likely to either walk or bike to the entrance. For major regional shared use paths that attract people travelling longer distances, off-street parking can be beneficial. The number of parking spaces should ideally be based on demand and include appropriate accessible spaces. However, vehicular parking is often constrained by the amount of property available. One method of determining parking demand is described in the Institute of Transportation Engineers publication, *Parking Generation*.
- Benches – Shared use path entrances often act as meeting places and benches allow visitors to rest while waiting for other path users. Path users may also wish to rest after a walk or bicycle ride. Benches should be accessible and should generally be placed to maximize the view of people passing by, or near a significant natural feature. It is generally not preferable to place a bench so that a person sitting on it has their back to the shared use path.
- Trash receptacles – For shared use paths that are regularly maintained by an agency or organization that picks up trash and handles graffiti and vandalism, trash receptacles can be provided at shared use path entrances and at regular intervals along the path.
- Water fountains and picnic tables – Water fountains are a welcome amenity for some users, and can also be designed to provide water for pets. Picnic tables are another welcome amenity for some users. In both cases, they should be accessible and should be placed away from the flow of shared use path traffic.
- Lighting – Lighting should be provided at conflict points such as intersection or mid-block crossings, transit stops, and other areas based on land use context and expected user volumes. Lighting may also be needed along the lengths of shared use paths to improve safety and security for paths that are open during evening hours.

Waysides are locations adjacent to a shared use path that provide a place for path users to rest, meet other path users, enjoy a view, or to orient themselves. They serve both practical and aesthetic purposes and can greatly enhance the user experience. Waysides come in many shapes and sizes from a bench along a shared use path, to pocket parks with restrooms, maps, and other amenities described above. Consider including cane-detectable signage that includes braille information to alert people with vision disabilities to the presence of the wayside. Include a description of the wayside amenities to assist the person in navigating and understanding the layout of the wayside.

5.6 Shared Use Path Intersection Design

Where shared use paths intersect roadways, the crossing design should minimize path users' exposure to traffic and minimize the speed differential at the points where travel movements intersect. Another goal is to provide clear messages regarding right of way to all users moving through an intersection in conjunction with design features that result in higher compliance where users are expected to yield.

Shared use path intersection can be at a mid-block location or a side path at an existing intersection of two roadways. The latter scenario follows design principles for separated bike lanes and are discussed in Chapter 6.

Any shared use path intersection design should consider the variable speed between the vehicles and path users, the available intersection sight distance and the traffic volumes. There are three primary design objectives:

- Alert the motorists and path users to the crossing,
- Communicate who has the obligation to yield to whom,
- Enable the motorists and/ or path users to fulfill their obligations.

Designers should have a firm understanding of mutual yielding behavior as discussed in Section 3.4 to achieve the above intersection design objectives. Additionally, attention should be given to ensuring that people with limited or no vision are given sufficient cues at intersections to prevent them from unintentionally moving into the street or a bike-only facility.

Illumination of the path/roadway intersection should be provided, especially on unlit paths. Curb ramps with detectable warnings must be provided at intersections, and the width of the curb ramp and detectable warnings should extend the full width of the shared use path.

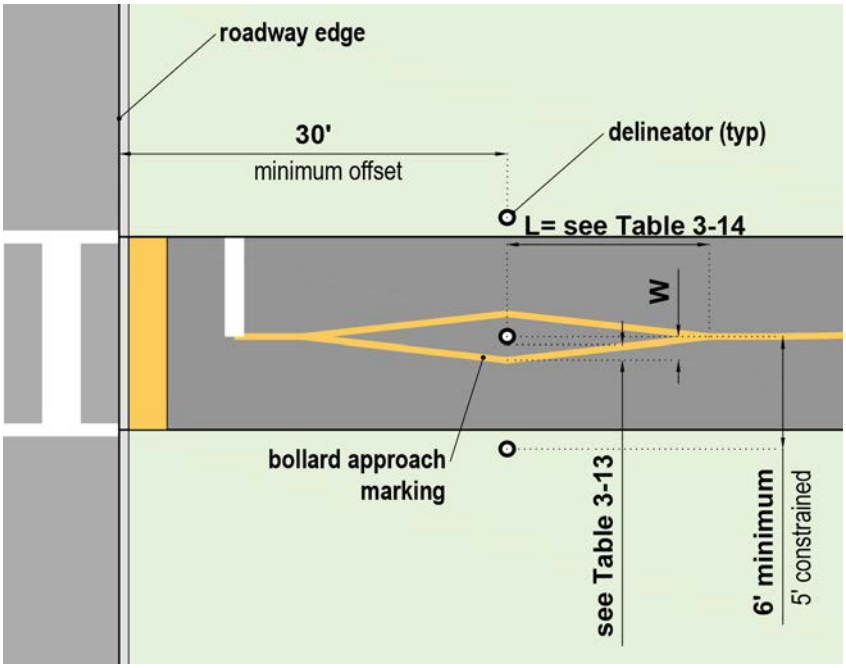
5.6.1. Restricting Motor Vehicles

Unauthorized use of shared use paths by motor vehicles occurs occasionally. In general, this is a greater issue on shared use paths that extend through independent rights-of-way that are not visible from adjacent roads and properties.

The routine use of bollards and other similar barriers (e.g., z-gates, fences) placed within the shared use path to restrict motor vehicle traffic is not recommended:

- Barriers such as bollards, fences, or other similar devices create permanent obstacles to path users, and bollards on shared use paths may be struck by bicyclists and other path users and can cause serious injury.
- Approaching bicyclists may shield even a conspicuous bollard from a following bicyclist's view until a point where the trailing bicyclist does not have sufficient time to react.
- Physical barriers are often ineffective at the job they were intended for—keeping out motorized traffic. People who are determined to enter the shared use path illegally will often find a way around the physical barrier, damaging shared use path structures and adjacent vegetation.
- Barrier features can also slow access for emergency responders.

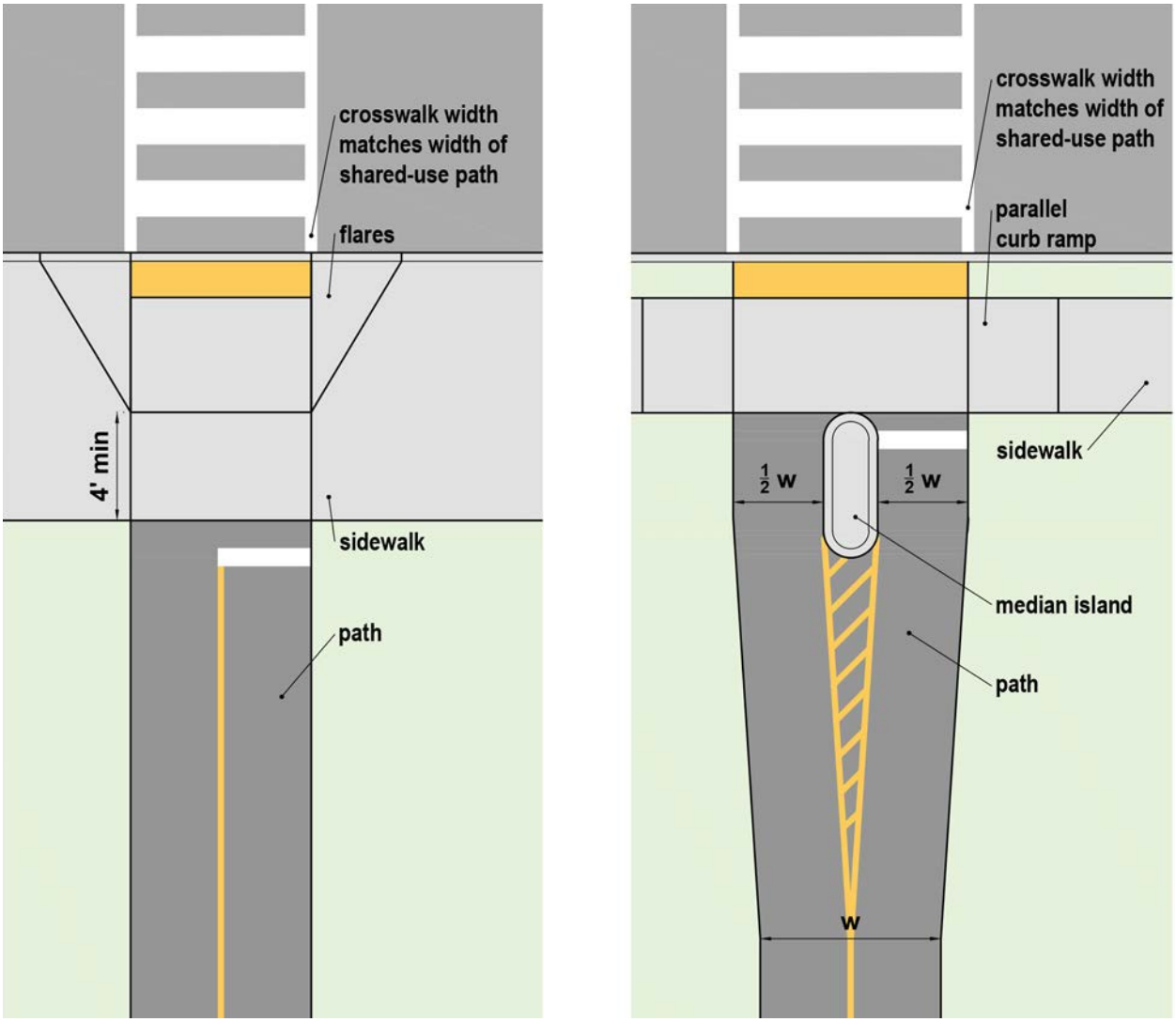
Figure 5-7: Bollard Approach Markings



Bollards should not be used unless there is a documented history of regularly unauthorized intrusion by motor vehicles, and other options have been unsuccessful in addressing the issue. A three-step approach may be used to prevent unauthorized motor vehicle entry to shared use paths:

1. Post signs identifying the entry as a shared use path and regulatory signs prohibiting motor vehicle entry. For example, the NO MOTOR VEHICLES (R5-3) sign may be placed at locations where roads and shared use paths cross, and at other path entry locations. Per the OMUTCD, this sign can be used to reinforce the rules of the roadway.
2. Design the shared use path point of entry such that its appearance clearly indicates it is not a vehicle access, and its physical design makes intentional access by unauthorized users difficult without presenting hazards to intended shared use path users. Figure 5-8 shows the preferred method of restricting entry of motor vehicles using a conspicuous center island that splits the entry way into two sections separated by concrete or low landscaping and features the following design elements:
   - » The path approach to the split should be delineated with solid line pavement markings to guide the path user around the split.
   - » Each section should be half the nominal shared use path width; for example, a 10 ft. shared use path should be split into two 5 ft. sections.

Figure 5-8: Path Curb Ramp and Apron



- Each half should be no more than 6 ft. wide to emphasize the nonmotorized use and discourage entry by motorized vehicles.
- Curbing used around the perimeter of the island should be beveled or mountable to reduce the risk of pedal strikes by bicyclists. A painted median island or a landscaped area flush to the path are alternative options to split the path access, but do not have the same effectiveness of restricting motor vehicles.
- The center island and selected vegetation should be designed to allow emergency and maintenance vehicles to enter the shared use path, if needed, by straddling the island and passing over the landscaping. Alternatively, it may be more appropriate to designate emergency and maintenance vehicle access via separate access drives adjacent to path access points, which can be secured by gates or fencing.

Assess whether signing and shared use path entry designs prevent or reduce unauthorized traffic. If motor vehicle incursion is isolated to a specific location, consider targeted surveillance and enforcement. Consider the reasons why the motor vehicle incursion is happening at that location and determine whether other changes to the path farther from the point of entry might discourage further motor vehicle intrusion. If unauthorized use persists, assess whether the problems posed by unauthorized vehicle entry exceed the risks and access issues posed by barriers. Where the need for bollards or other vertical barriers in the shared use path can be justified despite their risks and access issues, Table 5-6 summarizes design features that should be considered to make them as compatible with the needs of bicyclists and other path users as possible.

Table 5-6: Bollard Design Features and Considerations

Topic	Features and Considerations
Bollard Use	• Only installed in locations where vehicles cannot easily bypass the bollard. • Flexible delineators should be considered before installing rigid bollards to see if that resolves the issue; flexible bollards or spring-mounted delineators may reduce unauthorized vehicle access without causing the injuries discussed above.
Design	• Should be marked with retroreflective material on both sides. • Should be a minimum height of 40 inches and minimum diameter of 4 inches. Taller bollards may be used to reinforce visibility, but they may present potential hazards for handlebar strikes. Additional shy distance should be provided between taller bollards, which must be balanced with widths that prohibit motor vehicle intrusion.
Markings	• Striping an envelope around the approach to the bollard is recommended to guide shared use path users around the object (see Figure 5-7). The taper should be based on the design speed and follow guidance for markings in Section 3.6.3 to ensure they are visible to approaching shared use path users.
Installation	• Hardware installed in the ground to hold a bollard or post should be flush with the surface to avoid creating an additional obstacle. • Removeable bollards should be fully removeable and not of the hinged “lay down” type. There should be a permanently affixed cap that covers the open hole when the bollard is removed. All portions of the cover and receiver should be flush with the path surface when the bollard is removed, and the cap should be treated with a non-slip surfacing.
Placement	• Should permit passage for adult tricycles, bicycles towing trailers, and tandem bicycles that does not require the user to dismount or and cannot restrict access for people with disabilities. All users legally permitted to use the facility must be accommodated; failure to do so increases the likelihood that shared use path users will collide with the bollards. At a minimum, 4 ft. of clearance between bollards must be maintained, in compliance with pedestrian accessibility guidance. • Should be located to ensure adequate sight distance is provided to allow approaching users to adjust their speed to avoid hitting them. • Should not be located coincident with other decision points for bicyclists, as the combined recognition and decision processes for simultaneously avoiding the bollards and making additional yield or stop decisions may contribute to crashes. For example, bollards should not be placed immediately adjacent to sidewalk or street intersections, or at junctions with other paths. It is generally recommended they be located a minimum of 30 ft. ahead of the point where a bicyclist must make a yield, merge, or stop decision (see Figure 5-7). • Placing one bollard aligned with the centerline of the shared use path is preferred to avoid having a central gap that is not clearly identified for one direction of travel versus the other. When more than one bollard is used, use an odd number of bollards so that one bollard is always in the center (or on the centerline) of the shared use path.

5.6.2. Path Approaches to Intersections

Reducing Speeds

To reduce shared use path users' approach speeds, chicanes (i.e., horizontal curvature) can be incorporated at approaches to intersections where users must stop or yield, or where sight distance is limited. Care should be taken to end chicanes at least 30 ft. from bollards or intersecting sidewalks or roadways to allow the user to dedicate their attention to navigating the curves in the shared use path first, followed by the approaching intersection (rather than both at the same time). A solid center line stripe is recommended at chicanes to reduce the instances of bicyclists "cutting the corners" of the curves. Chicanes should not be designed with radii less than 15 ft. and should not accommodate a straight 'fastest path' if a bicyclist used the entirety of the path to navigate the turns.

However, in many instances there will not be sufficient right-of-way to provide a chicane approaching an intersection. These locations will rely entirely on pavement markings (Section 5.7.2), signing (Section 5.7.1), and appropriate sight lines (see Section 3.5) to communicate the presence of the path intersection.

The use of z-gates, bollards, or other physical obstructions within the shared use path to slow bicyclists or to force bicyclists to dismount is not appropriate approaching intersections (see Section 5.6.1).

Curb Ramps and Aprons

The opening of a shared use path at a roadway intersection should be at least the same width as the shared use path itself. If a splitter island is used, the combined shared use path widths on either side of the island should equal or exceed the width of the shared use path itself (see Figure 5-8 for a graphic representation and for details see Standard Construction Drawing BP-7.1). The splitter island may be paint-only or curbed, though paint-only treatments may be less visible leading to motorist access (see Section 5.6.1).

A curb ramp or blended transition should be the full width of the shared use path, not including any side flares of the curb ramp, if used. The approach should provide a smooth and accessible transition between the shared use path and the roadway. The ramp should be designed to be accessible to and usable by individuals with disabilities. Detectable warning surfaces should be placed across the full width of the ramp at the edge of the roadway, even when there are separate bicycle and pedestrian ways within the shared use path.

Unpaved shared use paths or trails that intersect with paved shared use paths should be provided with paved aprons extending a minimum of 20 ft. from the path edge.

Widening

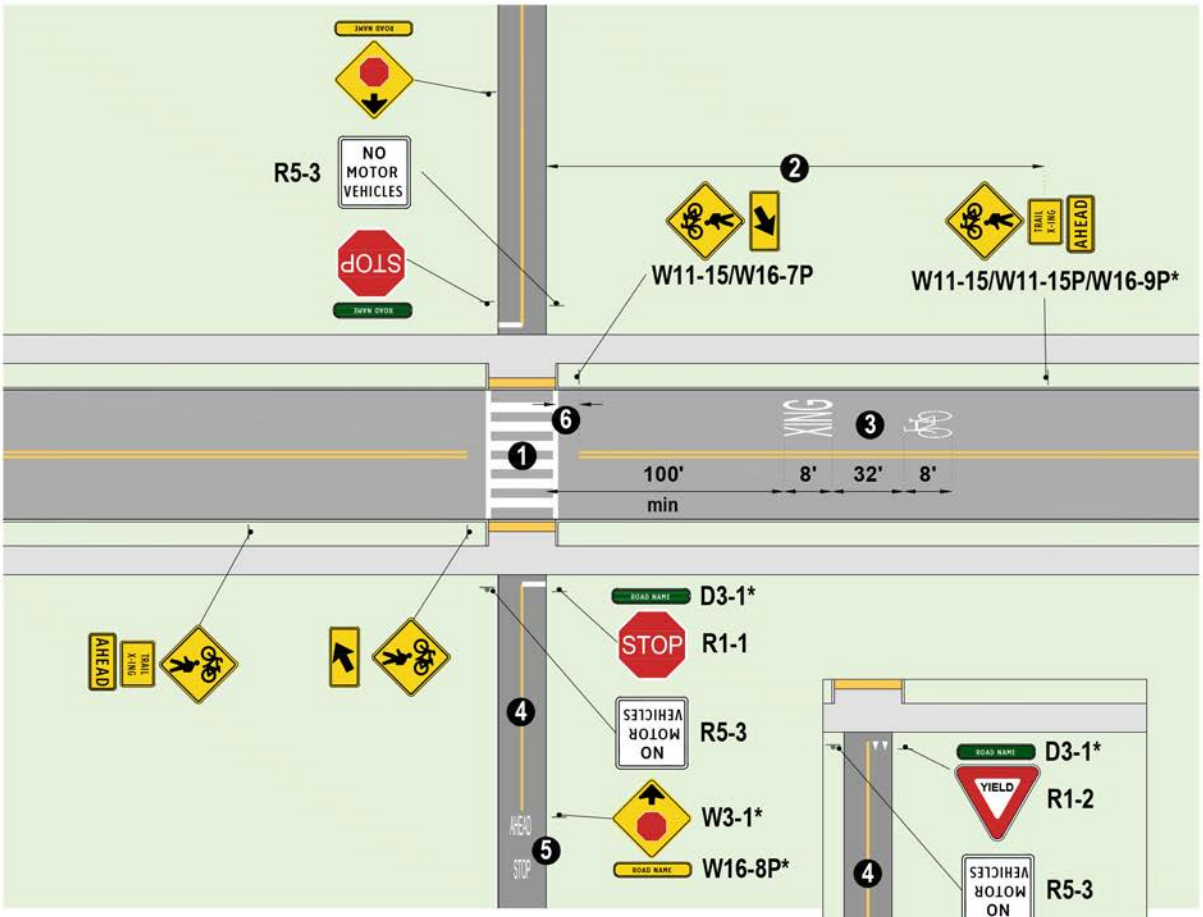
For locations where queuing at an intersection results in crowding at the roadway edge, consideration can be given to widening the shared use path approach. This can increase the crossing capacity and help reduce conflicts at shared use path entrances. Crosswalks should be widened to match the width of the shared use path.

5.6.3. Design of Mid-Block Crossings

Figure 5-9 through Figure 5-13 illustrate various examples of mid-block control treatments. These figures show typical pavement marking and sign crossing treatments. The diagrams are illustrative and are not intended to show all signs and markings that may be necessary or advisable, or all types of design treatments that are possible at these locations. Each figure assumes the appropriate minimum sight distances are provided for the roadway and the shared use path. See Sections 4.4.3, 4.4.4, and 6.4.1 for additional intersection countermeasures considerations including treatments to address motorist yielding.

It is preferable for mid-block crossings to intersect the roadway at a 90° angle to minimize the crossing distance and to maximize the intersection sight distance. Sight triangles and intersection sight distance are discussed in more detail in Sections 3.5.

Figure 5-9: Shared Use Path Stops or Yields



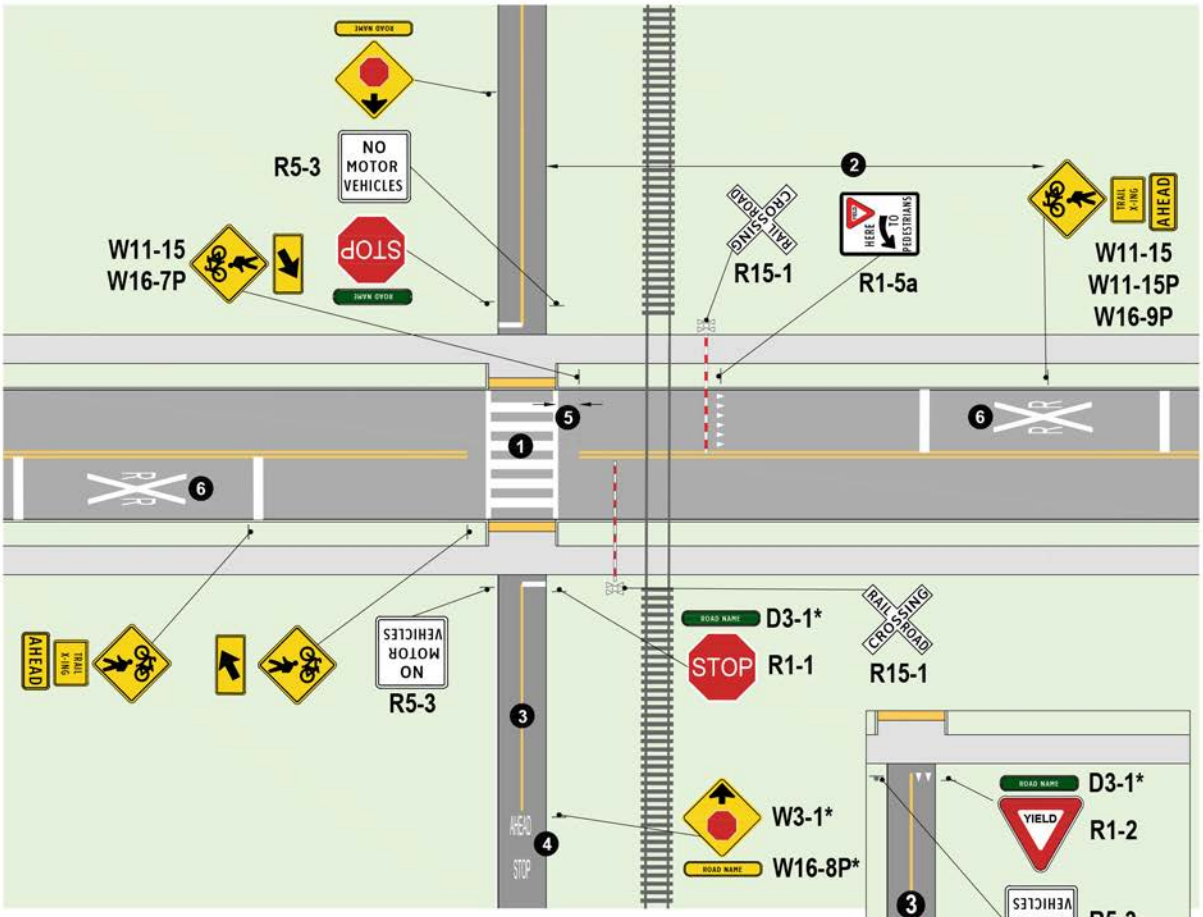
alternate: yield condition

Note:

* **Signs are Optional but Recommended**

1. crosswalk markings legally establish midblock pedestrian crossing
2. length varies: see MUTCD table 2C-4
3. optional roadway markings
4. shared-use path centerline as needed
5. optional pathway markings and signage
6. sign placement 4'-50' from crossing

Figure 5-10: Shared Use Path Stops or Yields near Railroad Crossing

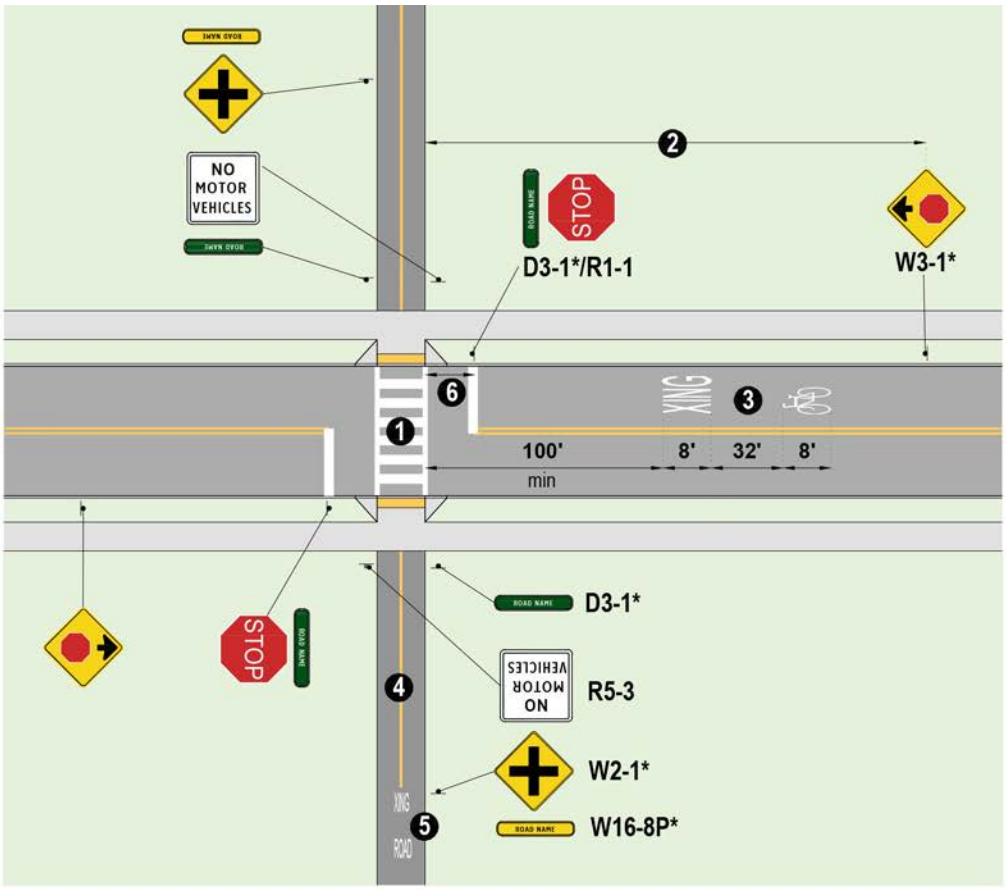


Note:

* **Signs are Optional but Recommended**

1. crosswalk markings legally establish midblock pedestrian crossing
2. length varies: see MUTCD table 2C-4
3. shared-use path centerline as needed
4. optional pathway markings and signage
5. sign placement 4'-5' from crossing
6. railroad crossing pavement marking

Figure 5-11: Road Stops

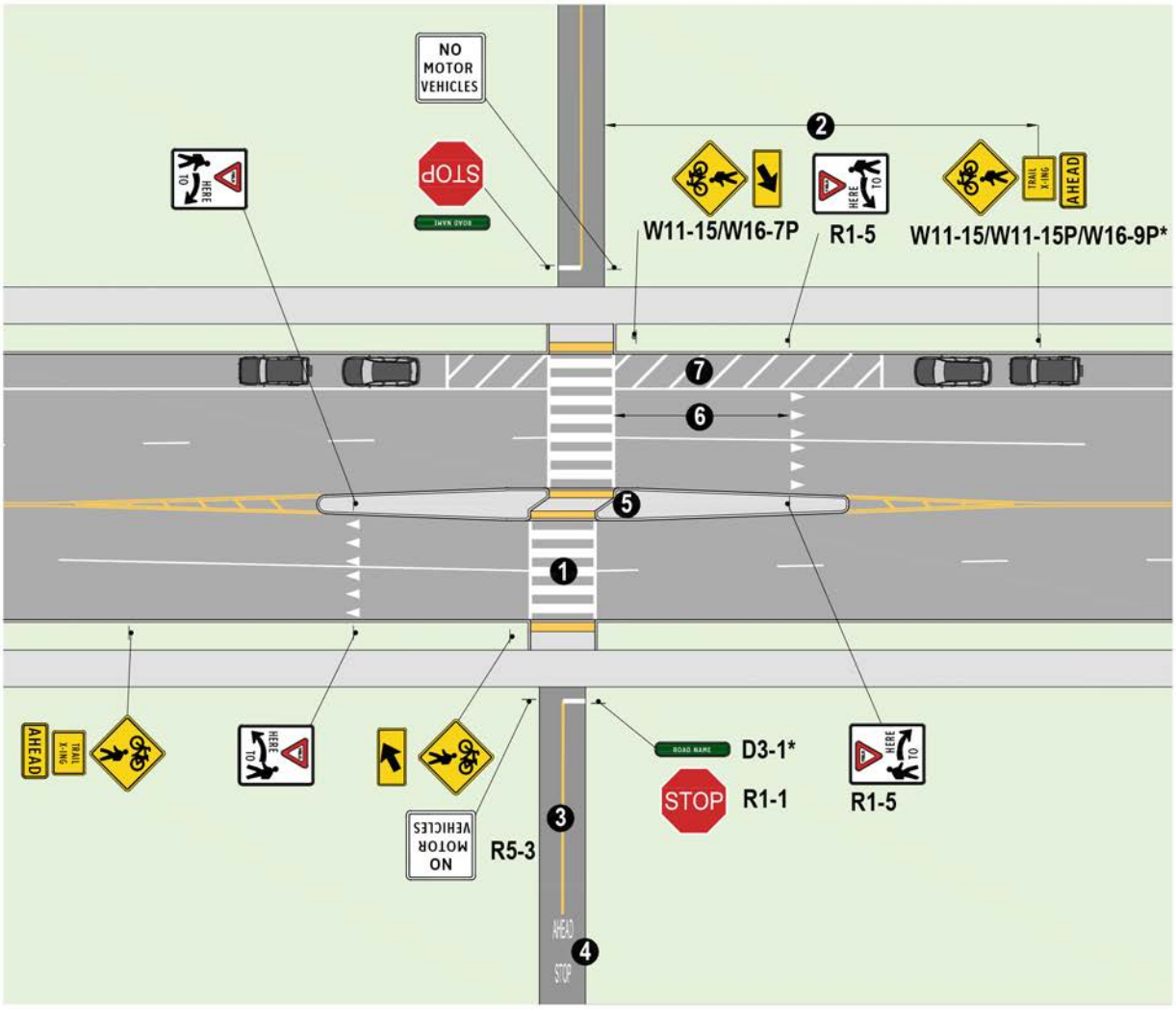


Note:

* **Signs are Optional but Recommended**

1. crosswalk markings legally establish midblock pedestrian crossing
2. length varies: see MUTCD table 2C-4
3. optional roadway markings
4. shared-use path centerline as needed
5. optional pathway markings and signage
6. sign placement 4'-50' from crossing

Figure 5-12: Multi-lane Road Uncontrolled with Advance Yield Line

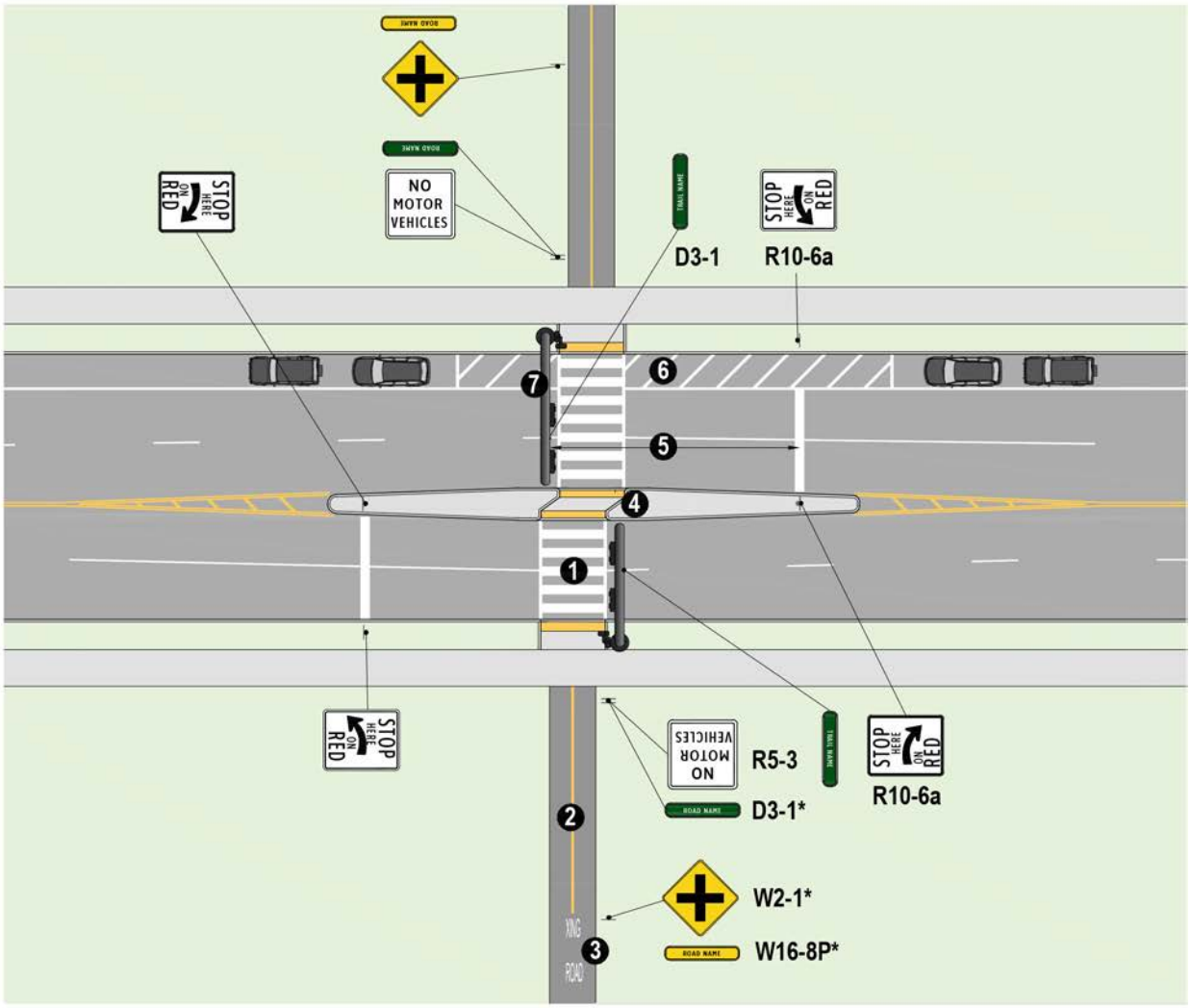


Note:

* **Signs are Optional but Recommended**

1. crosswalk markings legally establish midblock pedestrian crossing
2. length varies: see mutcd table 2C-4
3. shared-use path centerline as needed
4. optional pathway markings and signage
5. refuge median
6. yield bar placement 20'-50'
7. parking restricted

Figure 5-13: Multi-lane Road with Signals



Note:

* **Signs are Optional but Recommended**

1. crosswalk markings legally establish midblock pedestrian crossing
2. shared-use path centerline as needed
3. optional pathway markings and signage
4. refuge median (see Section 4.5.3)
5. stop bar placement 40' min from traffic signal
6. parking restricted
7. mast arm with pedestrian push button

5.7 Signing and Marking

5.7.1. Signs and Traffic Control

Primary guidance for traffic control signs can be found in chapters 2B and 9B of the OMUTCD; the information presented in this section is supplemental to that guidance and is specific to shared use paths.

For advance warning sign placements on shared use paths, the sign should be placed to allow adequate perception-response time. A minimum of 2.5 seconds of perception reaction time is recommended for all path users. The location of the sign should be based on the stopping sight distance needed by the fastest expected path user; however, the sign should not be located closer than 50 ft. from the location warranting the advance warning.

Shared Use Path Crossing Assembly

Roadway users may be warned of a shared use path crossing by using a Combined Bicycle/ Pedestrian Warning (W11-15) sign. On a roadway approach to a shared use path crossing, placement of an intersection or advance traffic control warning sign should be at (or close to) the distance recommended for the approach speed in Table 2C-4 of the OMUTCD.

The assembly consists of a W11-15 accompanied by a Downward Arrow (W16-7P) plaque mounted below the warning sign. This sign assembly should not be installed at the crossing if the roadway traffic is yield-, stop-, or signal-controlled. The Advance Shared Use Path Name (W16-8P) plaque may be mounted on the sign assembly (below the W11-15 sign) to notify approaching roadway users of the name of the shared use path being crossed.

At shared use path crossings that experience frequent conflicts between motorists and path users, or on multi-lane roadways where a sign on the right-hand side of the roadway may not be visible to all travel lanes, an additional shared use path crossing warning sign assembly should be installed on the left-hand side of the road, or on the crossing island, if present.

The W11-15 may be placed on the roadway in advance of a shared use path crossing. Again, this warning sign should not be used in advance of locations where the roadway is stop-, yield-, or signal-controlled. Advance warning sign assemblies may be supplemented with an AHEAD (W16-9P) plaque located below the TRAIL X-ING W11-15P plaque.

Traffic Control Regulatory Signs

YIELD and STOP signs are used to assign priority at controlled but unsignalized shared use path–roadway intersections. The choice of traffic control (if any) should be made with reference to the priority assignment guidance provided in Section 6.4, but YIELD signs are preferred over STOP signs where sight distances accommodate yield operation. The design and use of the signs are described in sections 2B and 9B of the OMUTCD.

When these signs are co-located with others on or near the same post, placement should not obstruct the shape of the STOP or YIELD signs.

Intersection and Advance Traffic Control Warning Signs

Advance traffic control warning signs announce the presence of a traffic control of the indicated type (YIELD, STOP, or signal) where the control itself is not visible for a sufficient distance on an approach for users to respond to the device. An intersection warning sign may be used in advance of an intersection to indicate the presence of the intersection and the possibility of turning or entering traffic.

On a shared use path approach to a roadway intersection, placement of an advance warning sign should be at a distance at least as great as the stopping sight distance of the fastest expected path user in advance of the location to which the sign applies. The advance placement distance should not be less than 50 ft.

An intersection or advance traffic control warning sign may carry a Advanced Street/Shared Use Path Name (W16-8P) plaque to identify the intersecting road or path, as appropriate for the approach.

Guide Signs

The purpose of guide and wayfinding signs on shared use paths is to inform users of intersecting routes, direct them to important destinations, and generally to give information that will help them proceed along their way in a simple and direct manner. Road Name (D3-1) and Shared Use Path Name (W16-8P) plaque should be placed at all shared use path–roadway crossings and considered at other path access points. This helps path users track their locations and can enhance personal security of users. They should also be used at junctions where one major shared use path crosses another. At mid-block crossings, the D3-1 sign may be installed on the same post with a regulatory sign.

Guide signs to indicate directions, destinations, distances, route numbers, and names of crossing streets should be used in the same manner as described in section 2D.50 of the OMUTCD.

Warning Signs

The MUTCD provides guidance for the application of warning signs on shared use paths. In general, the use of warning signs should be limited to locations where sight distance to the condition is limited or the condition is otherwise unexpected. Where pavement markings are not included around fixed objects or other physical features which could represent a crash hazard, the application of reflective materials on the object (e.g., bollard) or Type 3 Object Marker plaques in front of the obstruction should be considered where night time operation is allowed on the path.

5.7.2. Pavement Markings

Pavement markings can provide important guidance and information for path and roadway users. Pavement markings should be retroreflective. They should not be slippery or rise more than 0.16 inches above the pavement.

Center Lines

A yellow center line stripe may be used to separate opposite directions of travel where passing is inadvisable. The use of a center line stripe can be applied to the entire length of a facility, or only at specific locations. On shared use paths, the use of a center line stripe may be particularly beneficial in the following circumstances:

- For shared use paths with high user volumes (continuous stripe)
- On curves with restricted sight distance, or design speeds less than 14 mph (localized stripe)
- On unlit shared use paths where night-time riding is permitted (continuous stripe)
- Approaching intersections (localized stripe)
- Approaching obstructions within the center of the shared use path, such as bollards (localized stripe)

The use of the center line stripe may not be desired in parks or natural settings. However, on shared use paths where a center line is not provided along the entire length of the path, appropriate locations for a solid center line stripe should still be considered where described above.

A solid yellow center line stripe may be used on the approach to intersections to discourage passing on the approach and departure of an intersection. If used, the center line should be striped solid the length of the stopping sight distance from the edge of the sidewalk (or roadway, if no sidewalk is present). A consistent approach to intersection striping can help to increase awareness of intersections.

Stop and Yield Lines

Use and design of stop and yield lines is described in sections 3B and 9C of the OMUTCD. For shared use paths, stop or yield lines should be placed across the half-width of the path corresponding to the stop or yield-controlled approach. If used, the stop or yield line should be placed a minimum of 2 ft. behind the nearest sidewalk or edge of roadway if a sidewalk is not present.

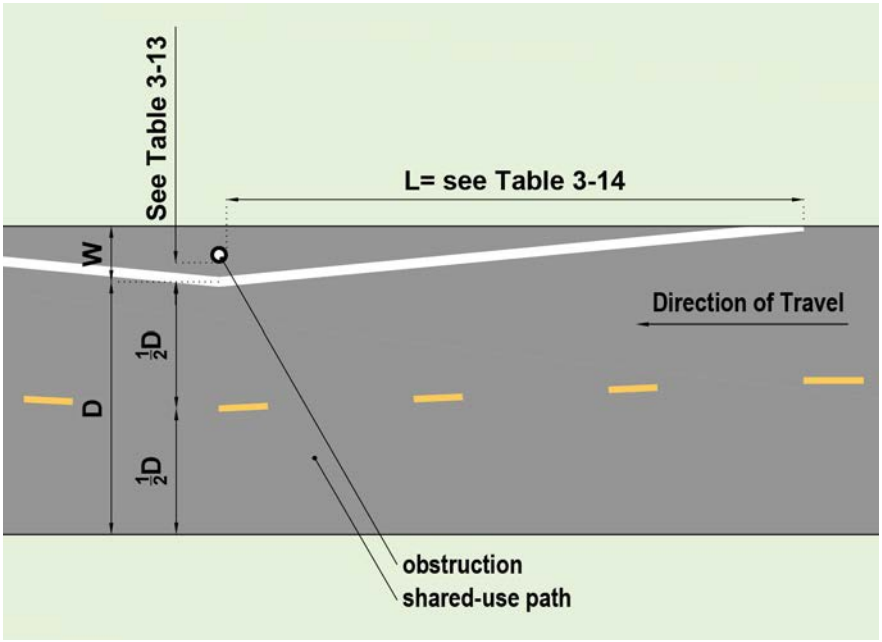
Obstruction Markings

Obstructions should not be located within the clear width of a shared use path because they present a crash hazard to bicyclists and other shared use path users. Where an obstruction on the traveled portion cannot be avoided (for example, in situations where bollards are used, see Section 5.6.1, or where a shared use path splits abuts a natural feature), channelizing lines of appropriate color (yellow for center line, otherwise white) should be used to guide bicyclists around it with sufficient advance warning of the presence of the obstruction by signs if the obstruction is not otherwise visible.

For obstructions located on the edge of the shared use path, an obstruction marking should be used as shown in Figure 5-14. The edge line or center line obstruction markings may be supplemented with buffer markings or colored pavement to further emphasize the hazard. At locations where a center line is present, the center line should shift as well to maintain relatively equal lane widths on either side of the path center line.

The markings should be located per the guidance for shy distance from obstructions in Section 3.6.2.

Figure 5-14: Obstruction Marking at Edge of Shared Use Path



Edge Lines

White edge line markings should be considered for use on shared use paths under the following situations:

- Where night-time use is permitted or routinely occurs
- Approaches to intersections to alert path users of changing conditions
- To separate pedestrians from bicyclists where the shared use path design includes a separate area for pedestrian travel
- When the shared use path width is changing significantly over a relatively short distance
- Approaches to marked constraints on the outside edge of the shared use path, such as entrances to tunnels or when passing bridge abutments
- To establish a shy distance from an obstruction that may otherwise not be noticeable, such as a short stretch of curbing or the foot of an adjacent retaining wall

Refer to Section 3.3.2 for more information on separation of shared use path traffic.

Marked Crosswalks

Marked crosswalks are recommended for all crossings of shared use paths at roadways; they are required at mid-block locations to create a legal crossing. At congested crossings, the shared use path can be widened on the approach (see Section 5.3.1) to provide a separate bicycle crossing (see Section 6.5.1) and pedestrian crosswalks to reduce conflicts and allow faster moving bicyclists to bypass pedestrians increasing the person crossing-capacity of the crossing.

Advance Word or Symbol Markings

Advance pavement markings may be used on shared use path approaches at crossings where the crossing is unexpected or where there is a history of crashes, conflicts, or complaints. If a supplemental word marking (such as HWY XING) is used, its leading edge should be located at or near the point where the approaching user passes the intersection warning sign or advance

traffic control warning sign that the marking supplements. Additional markings may be placed closer to the crossing if needed but should be at least 50 ft. from the crossing. Advance pavement markings may be placed across the entire width of the path or within the approach lane. Pavement markings should not replace the appropriate signs. Pavement markings may be words or symbols as described in Part 3 of the OMUTCD.

Narrow Path Conditions

At locations where paths with higher volumes of users must narrow below the recommended widths described in Section 5.3.1 consideration should be given to warning of the narrowed path condition. Fixed objects or natural features adjacent to the path that present potential hazards to path users should be properly marked following the Obstruction Markings guidance. Advance warning signs should be considered where sight distance is restricted to the object or feature including the use of the PATH NARROWS (W5-4a) sign. Appropriate channelization tapers should also be included to effect any changes in shared use path width ahead of the location. When narrower shared use path widths occur at discrete locations, consider including a marked center line to help organize opposing directions of travel.

Chapter 5 Endnotes

1 FHWA Shared-Use Path Level Of Service Calculator – A User's Guide

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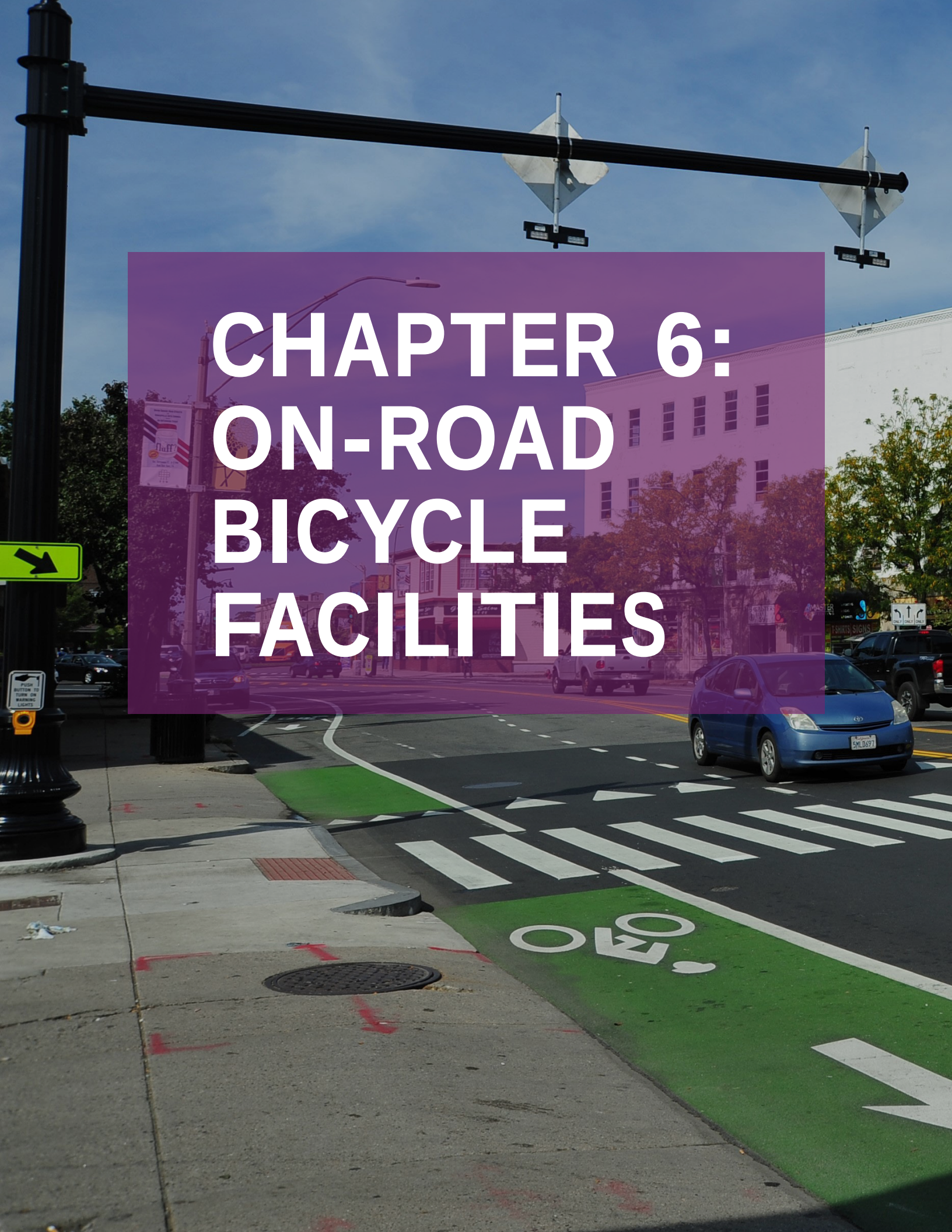


CHAPTER 6: ON-ROAD BICYCLE FACILITIES

Chapter 6: On-Road Bicycle Facilities

6.1 General

This chapter provides design guidance for accommodating bicyclists on roadways. Bicyclists have similar access and mobility needs as other users of the transportation system and may use the street system as their primary means of access to jobs, services, and recreational activities. The guidance provided in this chapter is based on established practice supported by relevant research where available. The described designs reflect typical situations; however, local conditions may vary, and engineering judgment should be applied.

6.2 Bicycle Routes

As discussed in Section 2.5.2, people bicycling are best accommodated when a connected and intuitive network of bicycle facilities is provided. Signed bicycle routes can help to identify streets and paths designated for bicycling and can provide bicyclists with wayfinding cues.

The network of bicycle routes consists of local and regional routes established by cities and local agencies, State Bike Routes established by ODOT, and U.S. Bike Routes established by the American Association of State Highway and Transportation Officials (AASHTO). Bicycle routes are typically established based on well-defined origins and destinations, which could include schools and other community resources, residential neighborhoods, business districts and employment centers, or connections to other bicycle routes.

Bicycle routes may be designed for different design user profiles. When planning and designing for Interested but Concerned Bicyclists, existing signed bicycle routes should be assessed to understand if they meet the needs of this design user.

Signing and Markings

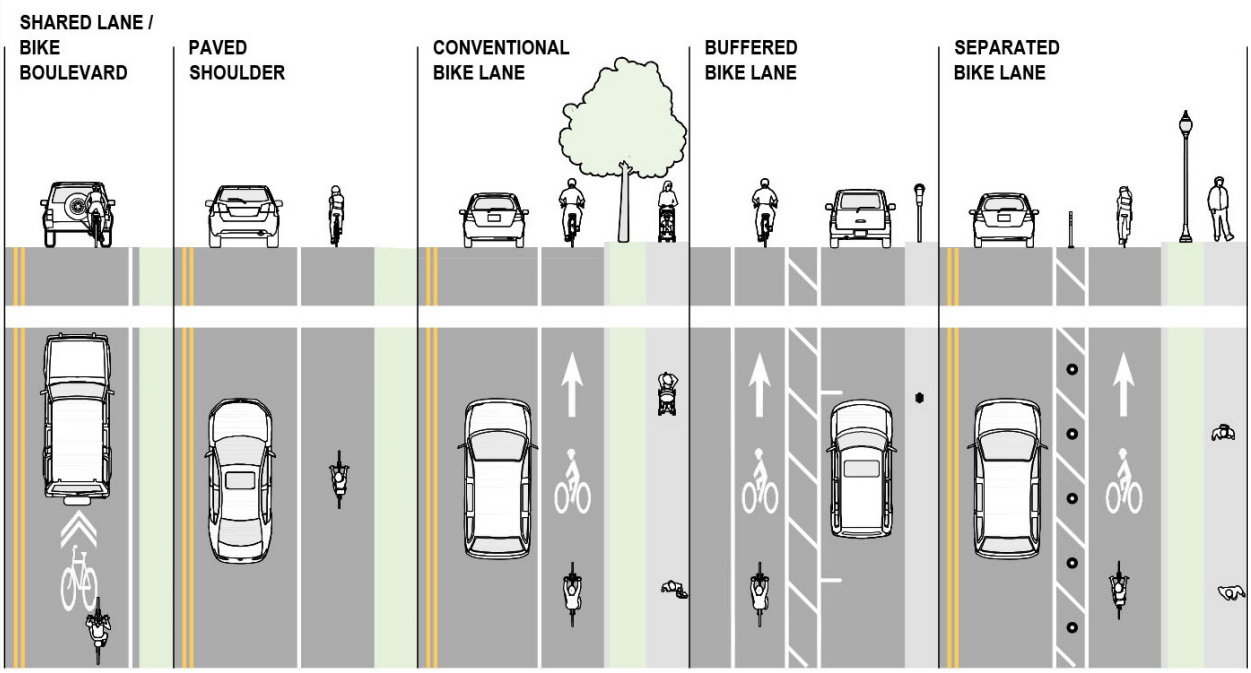
The bicycle network should include route identification and wayfinding signs to help bicyclists navigate each bike route. In additional to the bicycle facility pavement markings and signing discussed in Chapter 5 and Section 6.3, bicycle route signage should be used to help provide a visual identity to the bike network and differentiate those streets and paths from others that are not part of the defined bicycle network.

- Bicycle Route Guide signs (D11-1) and corresponding destination plaques (D1-1 through D1-3) serve as wayfinding signs that can help bicyclists identify and follow designated bicycle routes more easily and can provide directions to other bicycle routes or key community destinations. Bicycle Route Guide signs should be installed at appropriate intervals along the network, at locations where changes in route direction occur, and where bike routes intersect.

- Local and State Bicycle Route Signs (M1-8 and M1-8a) may be used to establish a unique identification for a specific local or State bicycle route. An M1-8a sign with "OH" at the top of the sign may only be used on routes designated as State Bicycle Routes. U.S. Bike Route Signs (M1-9 and M1-9 (Alternate).
-) are reserved for use on designated U.S. bike routes. These types of bicycle route signs should be supplemented by other bicycle guide signs and wayfinding signs where appropriate to inform bicyclists of changes in direction or key destinations along the route. Where two or more bike routes overlap, the routes should be signed with two or more separate signs instead of multiple routes on the same sign.

On ODOT-maintained roadways, sign locations should be approved by District Bicycle and Pedestrian Coordinators. Refer to *ODOT's State and U.S. Bike Route System Overview and Implementation Guide* for additional information including maintenance responsibilities.

Figure 6-1: On-Road Bikeway Types



6.3 On-Road Bicycle Facilities

The following section provides design guidance for various bikeways. Although this section refers to these as bikeways, designers should understand that these facilities are also used by people on scooters, skateboards, and other micromobility devices, all of which should be considered in the planning and design process. For general design considerations including lighting, drainage, and utilities in relation to bikeways, see Chapter 3. Bicycle travel should be safely accommodated at bridges, viaducts, tunnels (Sections 4.7 and 5.4); traffic signals (Chapter 8); interchanges and roundabouts (Chapter 9); transit stops (Chapter 10); and railroad crossings (Chapter 11).

6.3.1. Shared Lanes

Shared lanes are the most common bicycle accommodations since bicycles may operate on all roadways except where prohibited by ORC Section 4511.051. Shared lanes may be identified with signage and markings or be left unmarked. Sometimes marked shared lanes are provided as an interim strategy to enhance awareness of bicyclists' presence on the road where physical separation is desired but not currently feasible. Shared lanes are not recommended for roadways with speeds over 35mph (OMUTCD 9C.07.02).

The designs and dimensions for shared lanes differ by location, but attention to the following design features can make shared lanes more comfortable for bicyclists.

- Along the roadway, provide good pavement quality, adequate sight distances, roadway design that encourages slower motor vehicle operating speeds and lower traffic volumes, bicycle-compatible drainage grates and bridge expansion joints, and safe railroad crossings.
- At signalized intersections, provide appropriate signal timing and detection systems that respond to the presence of bicycles. See Chapter 8.
- At uncontrolled crossings, provide treatments that ensure bicyclists have opportunities to safely cross the intersecting roadway. If such features or conditions are not present, improvements should be implemented. See Low-stress Intersection Crossings in Section 6.5.6 for design guidance for more information.

Where bicyclists are operating in shared lanes, travel lane widths should generally be the minimum widths appropriate for the context of the roadway. In the past, it was common practice to provide wider outside lanes (14 ft. or greater) under the assumptions that motorists in such a lane could pass a person riding a bicycle without encroaching into the adjacent lane and that this practice would improve operating conditions and safety for both bicyclists and motorists. However, this is inconsistent with Ohio passing laws, and experience and research finds that this configuration does not adequately provide safe passing distance and that motorists generally do not recognize that this additional space is intended for bicyclists. Wider travel lanes are also associated with increases in motor vehicle speeds, which reduce comfort and safety for bicyclists. Wide lanes are therefore not recommended as a strategy to accommodate bicycling. Where wide lanes exist, roadways should at a minimum be restriped to reduce wide lanes to minimum lane widths. Additional space may be reallocated to other purposes such as bike lanes, wider sidewalks, etc.

The use of constrained width bike lanes (see Section 6.3.4) is preferable to a wide outside lane. However, the use of minimum constrained width bike lanes should be limited to constrained roadways where preferred minimum bike lane widths cannot be achieved after all other travel lanes have been narrowed to minimum widths appropriate for the context of the roadway. For bicycle lanes adjacent to on-street parking, designers must follow the guidance in Section 6.3.4.

Shared Lane Signs

On urban roadways with posted speed limits of 35 mph and below, the roadway lane may be marked as a shared lane with signage and shared lane bicycle markings. Signage options include:

- "BICYCLES MAY USE FULL LANE" sign (R4-11) may be used in situations where motorists must either change lanes in order to pass a bicycle at a safe distance when overtaking or operate at reduced speed behind bicyclists until an opportunity for safe passing is presented. Lanes less than 14.5 ft. are too narrow for a motorist to pass a bicyclist at a safe distance. Most general purpose lanes are 12 ft. wide or less, and wider lanes are discouraged due to safety. Given this, on most roadways the lane widths are insufficient to allow for a bicyclist and an overtaking vehicle to travel safely side by side within the lane.
- ORC Section 4511.27 states, in part, "When a motor vehicle.... passes a bicycle, three ft. or greater is considered a safe passing distance." The PASS [BICYCLE] MIN 3 FT sign (R3-H16) should be used at locations where a problem or crash history between motor vehicles and bicyclists exists. It may also be used at other locations based on engineering judgment.
- BICYCLE warning sign (W11-1) may be supplemented with an "IN LANE," "ON ROAD," "ON BRIDGE," or "IN TUNNEL" plaque. The use of this sign assembly may be desirable in unique situations where bicyclists may appear to motorists to be unexpectedly operating within the travel lane.

The BICYCLE warning sign (W11-1) supplemented with a "SHARE THE ROAD" plaque (W16-1P) should not be used to communicate a shared lane condition. While it was previously common practice to use this combination of signs to communicate a shared lane condition, research has shown that the "SHARE THE ROAD" message is unclear to both motorists and bicyclists.[1]

Shared Lane Markings

Shared lane markings are intended to let bicyclists know where to position themselves in the lane and to communicate to motorists that bicyclists are likely to occupy the travel lane. When using shared lane markings, there are three considerations: lateral placement, longitudinal placement, and intersection approaches/navigation.

1. Lateral placement: Shared lane markings should be marked on an alignment that represents a practical path of bicycle travel under typical conditions. For most streets, such as where on-street parking is present or where lane widths are less than 14.5 ft., this lateral placement should be the center of a shared travel lane. The lateral placement of a shared lane marking is measured from the center of the chevron marking to the face of the curb, gutter seam, edge of the pavement, or edge of on-street parking (see Figure 6-2).

   Where shared lane markings are not placed in the center of the lane, they should be placed a minimum of 4 ft. from the face of curb, gutter seam, or edge of the travel way. This minimum distance should be increased at locations where:

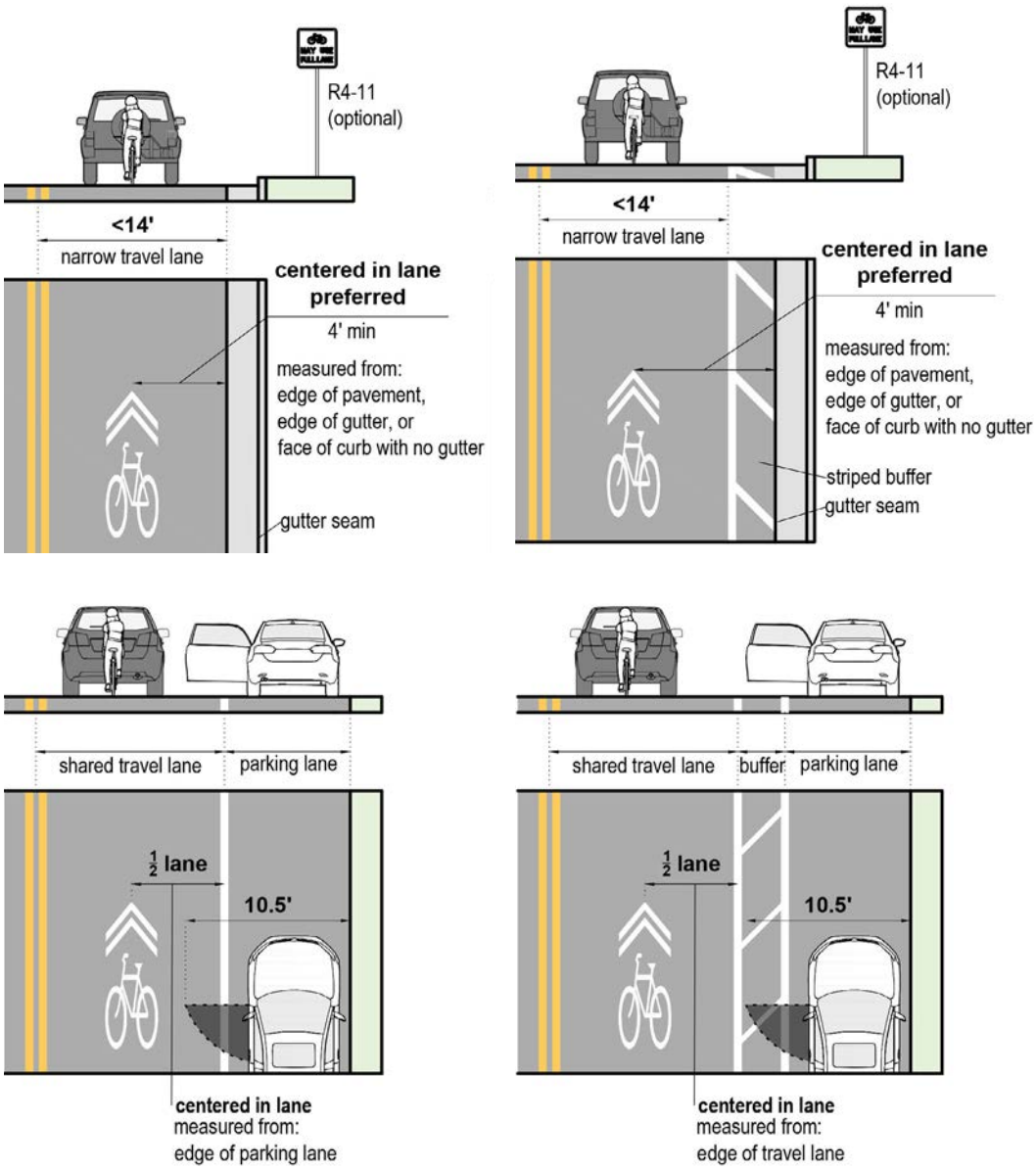
   » Existing drainage inlets or gutters create potential safety issues;

   » There is an inconsistent or rough roadway edge or gutter; or

   » Guardrails, rock outcroppings, walls, or other physical objects are located immediately adjacent to the travel lane.

   On a street with shared lanes designated as a bicycle route, if the bicycle route makes a left turn it may be appropriate to place shared lane markings within both the right and left lanes of the street.

Figure 6-2: Shared-Lane Markings Lateral Placement



2. Longitudinal spacing: Shared lane markings should be placed no more than 50 ft. downstream from an intersection and spaced at intervals no greater than 250 ft. thereafter (see Figure 6-3). If possible, the first marking after an intersection or driveway should be placed outside of the wheel path of turning vehicles to reduce wear.

   Unlike bike lanes, which provide a continuous visual presence, shared lane markings are intermittent. To compensate for this, it may be desirable to place shared lane markings at intervals of 50 to 100 ft. to increase motorist awareness of bicyclists and to provide additional guidance for bicyclists. This closer spacing may be desirable:

   » On streets with higher volumes of bicyclists where the shared lane condition fills a gap between bikeways;

   » To guide bicyclists through intersections, weaving areas, or turn lanes where there is higher potential for conflicts with motorists;

   » At locations with a history of conflicts or crashes between bicyclists and motorists;

   » In locations with limited sight distance including approaches to horizontal and vertical curves; or

   » In shared lane conditions within tunnels and across bridges.

3. Intersection navigation: Shared lane markings can also be used to provide guidance to a bicyclist to change lanes on approaches to intersections or to help them traverse an intersection. The markings should be located in a line of travel that allows the bicyclist time to merge while minimizing conflicts and unsafe motorists passing maneuvers. In these locations, the markings may be placed as close as necessary, less than the 50 ft. described above, to clearly identify the preferred travel path and maneuver. Example applications include:

   » Turns through intersections;

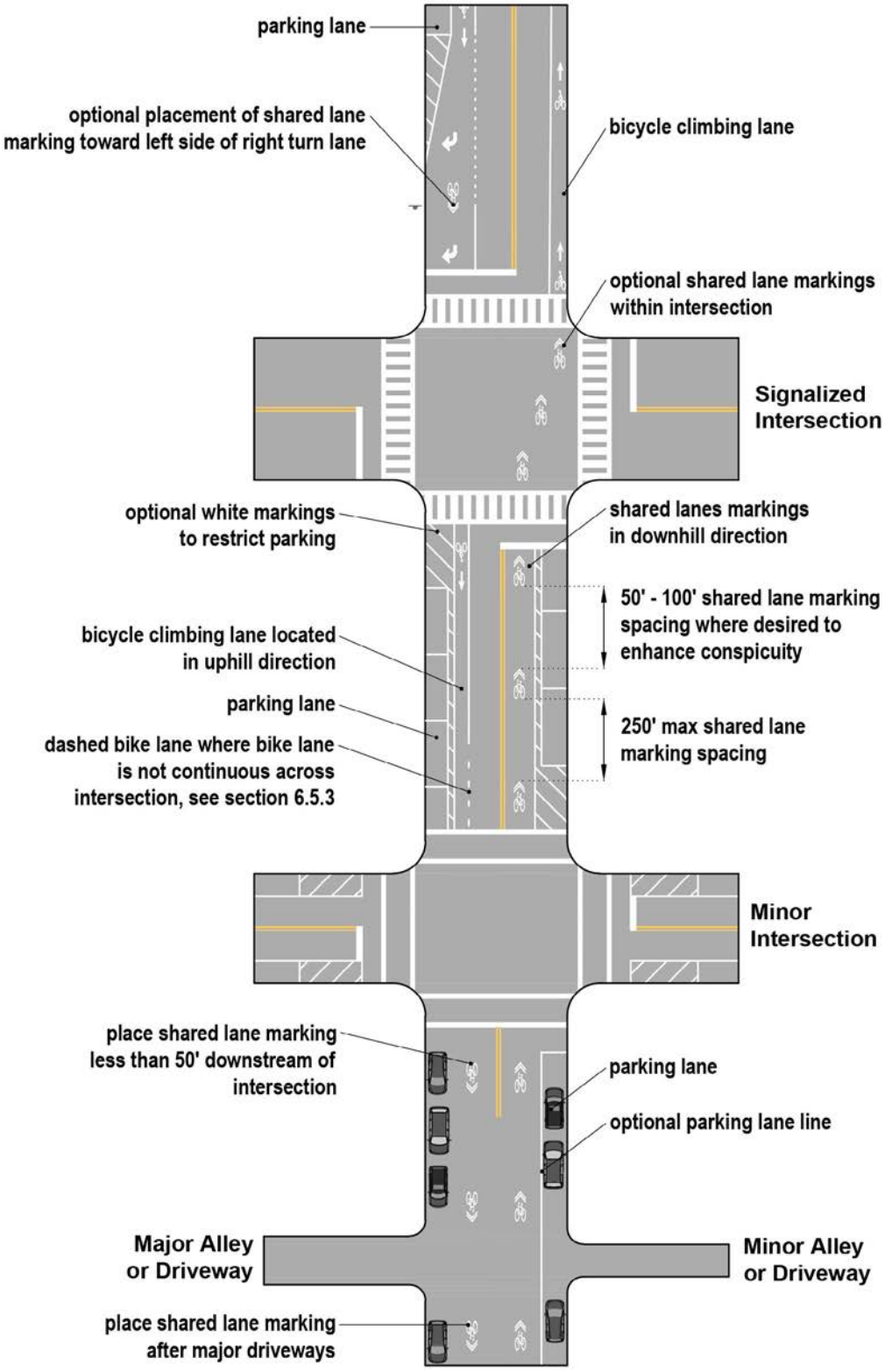
   » Navigation of lane shifts through intersections (see Figure 6-3);

   » Approaches to intersections where bicyclists must merge across one or more travel lanes; and

   » Approaches and crossings of railroad tracks (Chapter 11).

While the OMUTCD does not require marking parking lane lines, it may be desirable to mark the edge of on-street parking when bicyclists are expected. The parking lane line can provide a continuous point of reference to help bicyclists maintain their line of travel between shared lane markings. This can be further encouraged by adding optional door zone buffer markings (see Markings in Section 6.3.4) or the parking lane line. Wider parking lanes are discouraged on roadways where parking demand is low because the parking lane may appear to look like a bike lane or shoulder to motorists and bicyclists. The placement of a shared lane marking in the travel lane in these cases may cause confusion for bicyclists and motorists. In situations with low parking demand, it is generally preferable to provide bike lanes and consolidate parking to one side of the street or remove parking altogether.

Figure 6-3: Longitudinal Placement and Intersection Navigation Examples of Shared Lane Markings along a Roadway


parking lane
optional placement of shared lane marking toward left side of right turn lane
bicycle climbing lane
optional shared lane markings within intersection
Signalized Intersection
optional white markings to restrict parking
shared lanes markings in downhill direction
50' - 100' shared lane marking spacing where desired to enhance conspicuity
bicycle climbing lane located in uphill direction
parking lane
dashed bike lane where bike lane is not continuous across intersection, see section 6.5.3
250' max shared lane marking spacing
Minor Intersection
place shared lane marking less than 50' downstream of intersection
parking lane
optional parking lane line
Major Alley or Driveway
Minor Alley or Driveway
place shared lane marking after major driveways

6.3.2. Bicycle Boulevard

Bicycle boulevards, also commonly referred to as neighborhood bikeways or greenways, are low-volume and low-speed streets that enhance bicyclist safety and comfort through design treatments such as speed and/or volume reduction features, pavement markings, signage, and street crossing treatments. These treatments generally support through bicycle movements while discouraging non-local motorists from using them for through trips. Although bicycle boulevards operate as shared lanes, the following guiding principles define bicycle boulevards and set them apart from other local streets or shared lane roadways.

1. Managed motorized traffic volumes and speeds.
2. Prioritize bicyclist right of way at local street crossings.
3. Provide safe and convenient crossings at major streets.

Bicycle boulevards are intended to function as part of a low-stress bicycle network. The following summarizes the typical characteristics of a Bicycle Boulevard:

- Volumes and speeds: Motorist speeds and volumes should not exceed the criteria in Table 6-1. Traffic calming and diversion strategies should strive to achieve the preferred values in the table.
- Connections to local destinations: Routes should be parallel with and near major thoroughfares connected to major destinations (1/4 mile or less).

Table 6-1: Bicycle Boulevard Motorized Traffic Volume and Speed Performance Criteria

Minimize Motorized Through Traffic Volumes and Speed			
	Peak Hourly Traffic Volume* (vehicles/hr)	Average Daily Traffic Volume (ADT)	Operating Speed (mph)
Preferred	150	1,000	15
Acceptable	300	2,000	20
Maximum	450	3,000	25

*Assumed to be 15% of ADT

- Route directness: There is no excessive zigzag or circuitous routing.
- Topography: Longer, more gentle slopes are preferable to shorter, steep segments. Topography should be balanced with route directness.
- Feasibility of major street crossings: Major street crossings on routes should be designed to provide low-stress crossings as defined in Section 6.5.6.

Signing and Markings

A bicycle boulevard should provide route identification and wayfinding or bicycle guide signs to navigate a route. A combination of pavement markings and signage should be used to help give a visual identity to the corridor and differentiate the slow, multimodal street from other nearby streets.

- Bicycle Guide Signs (D11-1 and corresponding plaques) can help bicyclists identify and follow designated bicycle boulevard routes more easily.
- Follow the guidance in Section 6.3.1 for shared lane markings along a bicycle boulevard.
- The "BICYCLES MAY USE FULL LANE" sign (R4-11) may be used in situations where motorists must wait behind slower moving bicyclist or change lanes to pass a bicyclist at a safe distance.
- Warning signs, such as the W11-1 and W11-15 signs, should be used at major street crossings in conjunction with other major street crossing treatments discussed later in this section.
- Where stop signs are used at local street crossings, stop lines should be provided.
- Crosswalk markings should be used at all bicycle boulevard crossings where sidewalks are present.

ORC Section 4511.21 defines speed limits for different roadways in Ohio. It states that in the absence of a lower limit declared or established in accordance with the ORC, 25 mph should be the posted speed of a municipal corporation, except on state routes outside business districts, through highways outside business districts, and alleys. Where lower speed limits are authorized through the process defined by the ORC, a Speed Limit sign (R2-1) should be located at the beginning of the bicycle boulevard and on each block where the reduced speed limit applies to ensure motorists are aware of the reduced limit.

Motorized Speed and Volume Management

For roadways that do not currently meet the Bicycle Boulevard performance criteria shown in Table 6-1 but are intended to serve as Bicycle Boulevards, the street and intersections should be designed to change the motorist speed and/or volume to meet these criteria. The traffic calming and diversion strategies that can be considered to achieve this goal are identified in Table 6-2 and are further discussed in Chapters 4 and 7.

Table 6-2: Speed and Volume Management Treatments

Treatment	Volume Management	Speed Management
Horizontal Deflection		
Curb Extensions		✓
One-Lane Pinch Points	✓	✓
Chicanes	✓	✓
Traffic Circles		✓
Median Islands		
Street Width Reduction		
Road Diet		✓
Vertical Deflection		
Speed Humps & Tables	✓	✓
Raised Crossings	✓	✓

Treatment	Volume Management	Speed Management
Routing Restrictions & Traffic Diversion		
Signs and Markings	✓	
Diagonal Diverters	✓	✓
Median Diverter	✓	
Forced Turn Diverter	✓	

6.3.3. Paved Shoulders

Paved shoulders are portions of the roadway that accommodate stopped or parked vehicles, emergency vehicles, horse-drawn buggies, farm equipment or other slow-moving vehicles, bicycles, and pedestrians where sidewalks do not exist (See Chapter 4 for the design of shoulders for use by pedestrians). Paved shoulders have been shown to provide many safety benefits for all users, but are particularly important for improving comfort and safety for bicyclists on roadways that meet any or all of the following conditions:

- Traffic volumes that exceed 3,000 vehicles/day.
- Motor vehicle speeds greater than or equal to 50 mph.
- Inadequate sight distances for the typical operating speed or grades in excess of 5 percent.
- High percentages (> 10 percent) of heavy vehicles.

On two-way roads it is preferable to provide paved shoulders on both sides of the road; however, in constrained locations where pavement width is limited, it may be preferable to provide a wider paved shoulder on only one side of the roadway rather than to provide a narrow paved shoulder on both sides. This approach is not preferred but may prove beneficial in the following situations:

- Vertical curve - On uphill roadway sections, a paved shoulder may be provided to give slower-moving bicyclists additional maneuvering space, thereby reducing conflicts with faster moving motor vehicle traffic.
- Horizontal curve - On roadway sections with vertical or horizontal curves that limit sight distance, it can be helpful to provide paved shoulders over the crest and on the downgrade of a vertical curve, and on the inside of a horizontal curve.

Widths of Paved Shoulders

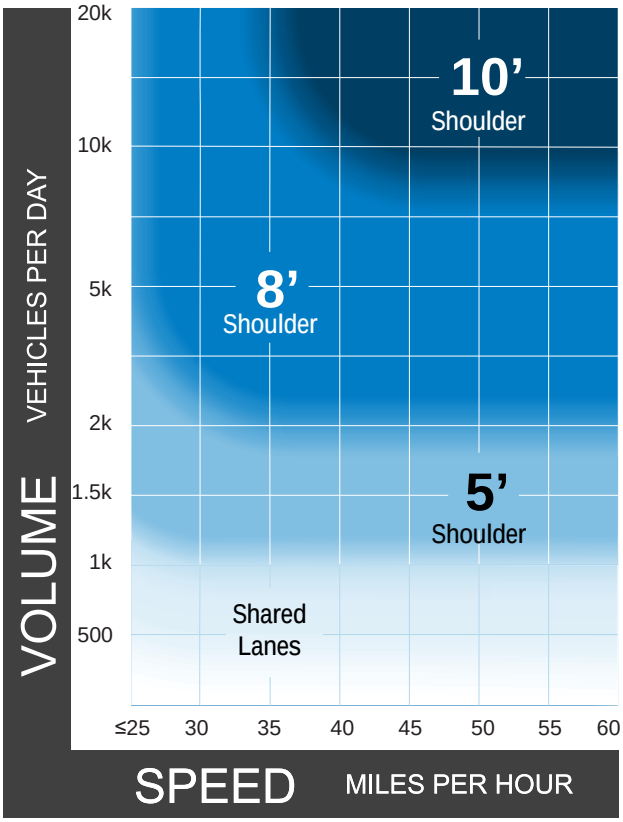
Where bicycle usage is expected, designers should ensure that paved shoulder widths meet both those outlined in Figure 6-4 and L&D Manual Volume 1, Section 301.2.

A paved shoulder width wider than those shown in Figure 6-4 is desirable where motor vehicle speeds exceed 50 mph; where heavy trucks, buses, or recreational vehicle volumes are considerable; or if static obstructions exist at the right side of the roadway. In Figure 6-4 a minimum paved shoulder width of 6 ft. is recommended from the face of a guardrail or concrete barrier (5 ft. in constrained areas) to provide additional operating width as bicyclists shy away from these roadside elements.

In highly constrained conditions where the shoulder widths shown in Figure 6-4 cannot be achieved and it is not possible to provide a shared use path separated from the road, it is preferable to provide a narrow shoulder rather than no shoulder. In these circumstances, a 3- or 4 ft.-wide shoulder provides some benefit to bicyclists if the shoulder does not contain rumble strips.

The usable paved shoulder width for bicycle travel is measured from the center of the edge line to the edge of pavement or face of vertical object (e.g., a curb or guardrail). If rumble strips are present, the usable paved shoulder width is reduced exclusive of that area.

Figure 6-4: Shoulder Widths to Accommodate Highly Confident Bicyclists on Rural Roadways



Notes

1 *This chart assumes the project involves reconstruction or retrofit in constrained conditions. For new construction, follow recommended shoulder widths in the ODOT L&D Manual Volume 1.*

2 *A separated shared use pathway is a suitable alternative to providing paved shoulders.*

3 *Chart assumes operating speeds are similar to posted speeds. If they differ, use operating speed rather than posted speed.*

4 *If the percentage of heavy vehicles is greater than 10%, consider providing a wider shoulder or a separated pathway.*

Shoulder Surface Quality

Surface conditions and pavement smoothness are important for bicyclist control, comfort, and safety. Surface defects can be a significant contributing factor to bicyclist crashes. In addition to the surface design parameters specified in Chapter 3, designers should consider the following maintenance and design recommendations to eliminate or reduce hazards to bicyclists:

- Address paved shoulders or pavement edges on open sections of roadway that have irregular edges or sharp drop-offs.
- Regularly street sweep shoulders to keep them clear of gravel, glass, and other debris.
- If raised pavement markers are used, consider installing the makers on the travel lane side of the edge line and use reflective markers that have beveled or non-abrupt edges.
- Pave at least 10 ft. of a low-volume driveway approach and at least 30 ft. of a high-volume driveway or unpaved road approach to prevent loose gravel from spilling or being carried onto the shoulder or traveled way. Where practical, the paved section of the approach to the highway should be sloped away from the highway to reduce the amount of loose material tracked into the shoulder. This should not be done at the expense of right of way (ROW) if the project is not otherwise acquiring ROW specifically for the driveway reconstruction.

- If paved shoulders are to be widened and the entire roadway is not resurfaced, saw cut at the proposed edge line and mill the existing surface to provide one continues finished shoulder.

Rumble Stripes and Rumble Strips

Rumble stripes are milled longitudinal rumble strips placed on the edge line. Where necessary, rumble stripes are preferred to rumble strips in areas designated as bicycle routes or having substantial volumes of bicycle traffic as they do not decrease the available shoulder width for bicycle travel. Rumble strips are placed in the shoulder outside of the edge line and generally should not be used where bicyclists are expected unless the shoulder is wide enough to accommodate the rumble strips and still provide a minimum clear width, see Figure 6-4.

When present, the rumble stripe (or strip) pattern should not be continuous but should consist of an alternating pattern of gaps and strips, each 12 ft. and 48 ft. respectively in length. Also, gaps should be provided in the rumble stripe pattern ahead of intersections, crosswalks, driveway openings, and at other locations where bicyclists are likely to cross the shoulder. Refer to Section 1415 of the TEM for the design of rumble stripes and strips.

Bicyclist Right of Way Considerations at Intersections

ORC 4511.44 notes that "[t]he operator of a vehicle, streetcar or trackless trolley about to enter or cross a highway from any place other than another roadway shall yield the right of way to all traffic approaching on the roadway to be entered or crossed." As such, a bicyclist operating on a shoulder must always yield the right of way to motorists. Bicyclists operating on the paved shoulder may not be aware of these requirements. In order to accommodate bicyclists along a paved shoulder and clearly communicate the right of way to all roadway users, designers may consider the following options:

- Option 1: A bicyclist operating on the paved shoulder may merge with traffic. Pavement markings (Shared Lane Marking) and signage may be installed to encourage bicyclist to merge into the travel lane if the speeds are 35 mph or less. Any rumble strips should be terminated prior to this merge area. Warning signing may be provided warning bicyclists of their responsibility to yield when operating on the paved shoulder such as at intersections with high turning volumes. Depending on the roadway context, including motorist operating speeds and volumes, this approach may not meet the goal of accommodating bicyclists of all abilities.
- Option 2: The paved shoulder may be converted to a bike lane as it approaches intersections or driveways. By designating the area as a bike lane instead of a paved shoulder, the bike lane will constitute part of the roadway, bicyclists would have the right of way at intersections, and turning vehicles would be required to merge into the bike lane to make right turns. Designers may provide a regulatory sign identifying "Turning Vehicles Yield to Bikes" on state and local roads. This option may better accommodate bicyclists of all ages and abilities and should always be considered if speeds are greater than 35 mph.

Example treatments for these paved shoulder options are further discussed in Section 6.5.7.

6.3.4. Bicycle Lanes

Bicycle lanes (bike lanes) are one-way bikeways designated for preferential use by bicyclists that typically carry bicycle traffic in the same direction as adjacent motor vehicle traffic and are distinguished from traffic lanes by striping, signing, and pavement markings. Buffered bike lanes are striped on-street bike lanes paired with a painted buffer space separating the bike lane from the adjacent motor vehicle travel lane and/or parking lane to increase the comfort of bicyclists.

Figure 3-3 identifies the roadway conditions suitable for bike lanes to accommodate the comfort of an Interested but Concerned Bicyclist, but bike lanes can be provided to accommodate bicyclists on any roadway that legally permits bicyclist use.

In most cases, bike lanes should be provided on both sides of two-way streets. A bike lane provided on only one side may invite wrong-way use. The following scenarios note when it may be acceptable to provide a bike lane on one side and how to select which side:

- On streets where downhill grades are long enough to result in bicycle speeds similar to typical motor vehicle speeds, a bike lane may be provided only in the uphill direction, with shared lane markings in the downhill direction. This design can be especially advantageous on streets where fast downhill bicycle speeds have the potential to increase the likelihood of crashes with fixed objects, particularly in locations with on-street parking.
- Where a roadway narrows on one side of the roadway for a short segment with an otherwise continuous bike lane.
- Where an adjacent parallel roadway of similar width provides a bike lane in the opposing direction.

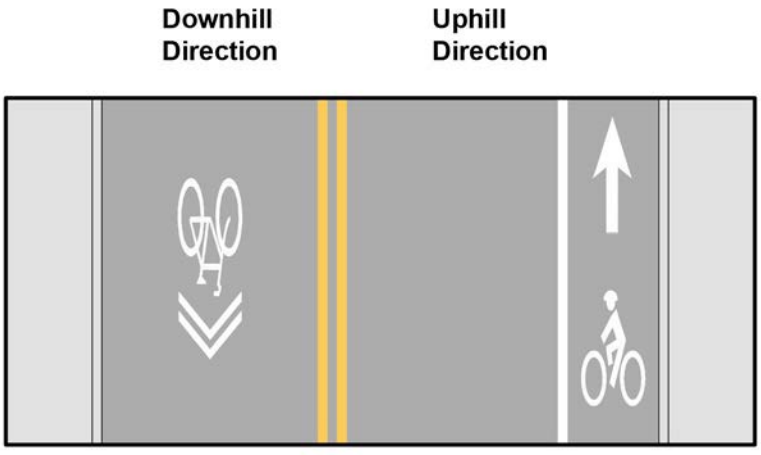
When a bike lane is only provided in one direction, shared lane markings should be added in the opposing direction if the roadway speed is 35mph or below. See Section 6.3.1 for shared lane design.

Width

The widths prescribed in Table 6-3 accommodate a person's operating space, occasional passing, and shy distances to vertical elements as discussed in Chapter 3. Chapter 7 provides guidance on when narrowing travel lane widths or reducing the number of travel lanes to achieve desired bike lane widths may be appropriate.

The width of a bicycle lane does not include the gutter adjacent to a curb. Where a bicycle lane is

Figure 6-5: Shared Lane Marking and Bike Lane on Steep Street



adjacent to a gutter, the width of the bicycle lane should be measured from the edge of the gutter to the center of the bike lane line. Where a bicycle lane is adjacent to a curb with no gutter, the bicycle lane width should be measured from the face of curb to the center of bike lane line. On streets with on-street parking, the bike lane width should be measured from the center of the parking line or buffer line to the center of the bike lane line.

In addition to the design values presented in Table 6-3, consider the following when designing bike lane widths:

- Bike lanes wider than the shown minimum should be considered:
  - in locations with high parking turnover;
  - where side-by-side bicycle travel is desired;
  - where roadways have irregular edges or sharp drop-offs;
  - where bicycle lanes are positioned between two moving travel lanes, such as a turn lane and through lane; or
  - on roadways that have more than 5 percent heavy vehicles, posted speeds over 30mph or AADT over 6,000.
- On extremely constrained, low-speed roadways with curbs but no gutter, where the preferred bike lane width cannot be achieved despite narrowing all other travel lanes to their minimum widths, a 4 ft. wide bike lane can be used.
- Where wider bike lanes are feasible, a buffer may reduce incidences of motorist attempting to use the bike lane as a travel lane or parking lane. See Section 6.3.5. Alternatively, a wide bike lane may include green colored pavement to discourage motorist use.

Table 6-3: Bike Lane Zone Widths

One-Way Standard Bike Lane Width Criteria		
Bike Lane Description	**Minimum Width (ft)**	**Constrained Width (ft)**
Adjacent to curb[1] or edge of pavement	5	4
Between travel lanes or buffers	5	4
Adjacent to parking[2]	6	5
Intermediate or sidewalk level raised bike lane[1]	5.5	5
To allow side-by-side bicycling or passing	8	7

[1] Exclusive of the gutter unless the gutter is integrated into the full width of the bike lane

[2] Raised bike lanes adjacent to parking should have a minimum width of 7 feet

Bicycle Lanes on One-Way Streets

On one-way streets, bike lanes should normally be on the right-hand side of the roadway. A bike lane may be placed on the left side if there are a significant number of left turning bicyclists or if a left-side bike lane would decrease conflicts, such as those caused by bus stops, heavy right-turn movements, deliveries, or on-street parking.

Bike lanes should typically be provided on both streets of a one-way couplet. If a one-way roadway pair in the opposite direction does not exist or would significantly increase a bicyclist travel time due to out of direction travel, there may be an increase in wrong way riding. If sufficient width exists, a counter flow bike lane can also be added to provide for two-way bicycle travel on a one-way street. For a bike lane to function as intended when built against the dominant flow of traffic on a one-way street, the following features should be incorporated into the design:

- The counter flow bike lane should be placed on the correct side of the roadway consistent with the ORC (i.e., on the left-hand side from the motorist's perspective).
- A bike lane should be provided for bicyclists traveling in the same direction as motor vehicle traffic. If there is insufficient room to provide a bike lane in the dominant flow direction of the street, shared lane markings should be considered to emphasize that bicyclists must share the travel lane on this side of the street.
- Where parking is present along a counter flow bike lane, motorists leaving a parking space may have difficulty seeing oncoming bicyclists in the counter flow bike lane, as sight lines may be blocked by other parked vehicles. For this reason, the provision of counter flow bike lanes should be discouraged where high-turnover parking is present on the same side of street.
- Bike lane symbols and directional arrows should be used on both the approach and departure of each intersection, to remind bicyclists to use the bike lane in the appropriate direction, and to remind motorists to expect two-way bicycle traffic.
- Centerline markings along the left side of the counter flow bike lane should be provided where passing is prohibited in both directions.
- Medians or traffic separators should be considered to provide more separation between motorists and bicyclists traveling in the opposing direction, particularly at intersections. This treatment is required when posted speeds exceed 35 mph.
- At intersecting streets, alleys, and major driveways, DO NOT ENTER signs and turn restriction signs should include a supplemental EXCEPT BICYCLES plaque to establish that the street is two-way for bicyclists.
- At traffic signals, signal heads should be provided for counter-flow bicyclists, as well as suitable bicycle detection measures. A supplemental plaque that says BICYCLE SIGNAL may be needed beneath the signal to clarify its purpose.

Signage

The following describes common signs needed where bicycle lanes are present. Section 9B of the OMUTCD provides additional guidance on bike lane signage.

BIKE LANE (R3-17) signs may be placed as needed or at periodic intervals along a bike lane (see Figure 6-6). Spacing of the sign should be determined by engineering judgment based on the prevailing speed of bicycle and other traffic, block length, and distances from adjacent intersections, but should not be installed in a manner that creates sign clutter. Bike lane markings are typically used more frequently than BIKE LANE signs, but where the BIKE LANE sign is used it should generally be placed adjacent to a bike lane pavement marking. The sign may be located on an existing post/utility pole when present.

The standard BIKE LANE (R3-17) sign with the AHEAD (R3-17aP) plaque may be placed in advance of the start (upstream end) of a bike lane. These signs are often considered at locations where the bike lane may be unexpected or there are sight distance restrictions to the bike lane.

The BIKE LANE sign with the ENDS (R3-17bP) plaque may be used in advance of the end of a bike lane to warn that a bike lane is ending. The BIKE LANE ENDS sign should always be used where a bike lane changes to an unmarked paved shoulder, for example at the urban or suburban fringe, but should not be used at temporary interruptions in a bike lane, such as where a bike lane is dropped on the approach to an intersection and resumes immediately after the intersection.

A BIKE LANE ENDS warning sign may be used in advance of a BIKE LANE ENDS regulatory sign, to warn bicyclists and motorists of the upcoming condition. A BICYCLES MAY USE FULL LANE sign (R4-11), BICYCLE warning sign (W11-1), and/or shared lane markings may be installed downstream of the merge area.

If motorists stopping, standing, or parking in a bike lane is a known problem, then, local jurisdictions should consider installing the NO PARKING BIKE LANE signs (R7-9 or R7-9a) or other signs restricting these activities.

For locations where wrong-way riding by bicyclists is frequently observed in bike lanes, the WRONG WAY and RIDE WITH TRAFFIC plaque (R5-1b and R9-3cP) may be used.

For locations where warning or regulatory signs are not applicable to bicyclists, an EXCEPT BICYCLES plaque should be used to supplement the warning or regulatory sign. These plaques may be applicable to supplement a variety of signs, such as DO NOT ENTER, NO OUTLET, ONE WAY, ALL TRAFFIC MUST TURN RIGHT, etc. The R3-7bP version of the sign should only be used with other regulatory signs; the version with black letters on a warning sign panel should only be used with other warning signs.

Markings

As detailed in Section 9C of the OMUTCD, a bike lane is designated for preferential use by bicyclists with a white line and bike lane symbol markings or word markings. The markings should be supplemented with the directional arrow marking indicating the correct direction of travel in the bike lane. Although the white line may be a normal width (4 to 6 inch wide), a wider width should be considered where additional emphasis is appropriate, such as roadways with higher motorist speeds and volumes. Wider markings can have the added benefit of improving the longevity of the markings.

Bike lane symbol markings should be placed no more than 50 ft. downstream from an intersection and spaced at intervals based on engineering judgement thereafter (see Figure 6-6). Spacing at or below 250 ft. may provide additional flexibility in urban areas. The first marking after an intersection or driveway should be placed outside of the wheel path of turning vehicles, to reduce wear. Additional bike lane symbols may be placed at closer intervals.

Bike lane symbols may be closer than 250 ft. where potential conflicts between bicyclists and motorists are higher, such as approaches to areas with significant parking turnover, at the near- and far-side of intersections and driveways, and adjacent to turn lanes. In suburban and rural areas, with long distances between intersections and little roadside activity, bike lane symbols may be as far apart as 1,000 ft. or more.

Designers should also consider conflict markings at intersections and driveways as discussed in Section 6.5.1.

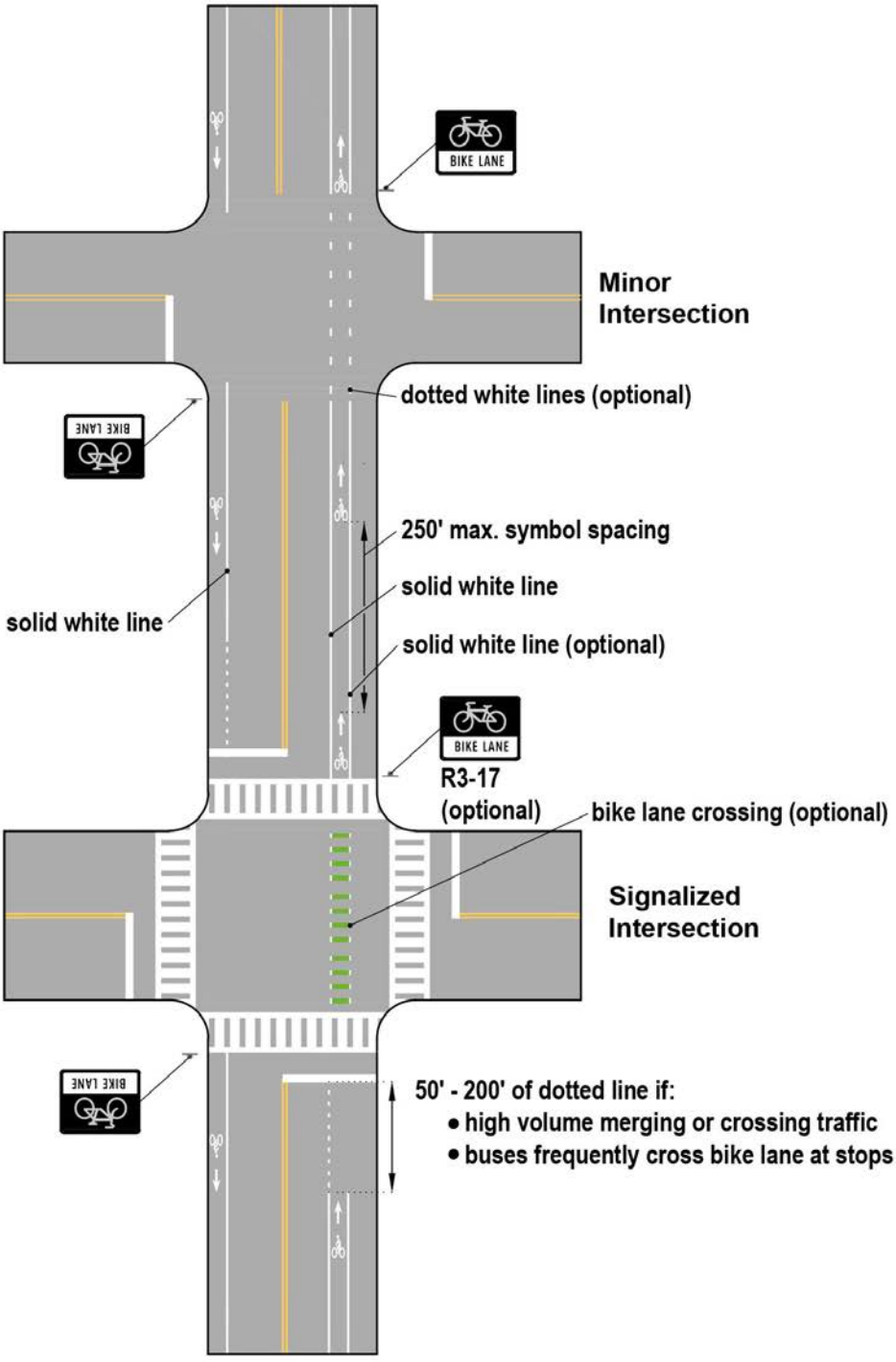
Green-Colored Pavement (Interim Approval)

Green-colored pavement is beneficial to supplement other bikeway pavement markings to communicate to road users where portions of the roadway have been designated for exclusive or preferential use by bicyclists, and to enhance the conspicuity of a bicycle lane, bike lane symbol, bicycle lane extension, bicycle crossing, bicycle box, or two-stage bicycle turn box. Green-colored pavement is an optional treatment that may be used per FHWA Interim Approval IA-14.2.

If green-colored pavement is used, designers should consider the longevity of the marking materials, the installation methods, and the expected motorist wheel paths to reduce long-term maintenance. For example, thermoplastic green markings may be appropriate for lane extension markings, two-stage bicycle turn boxes, and approaches to intersections where vehicles are expected to traverse the markings, whereas epoxy or methyl methacrylate (MMA) green markings may be appropriate where few vehicles would traverse the markings or where long areas of green are desired (such as within bike boxes or along areas with on-street parking). Thermoplastic pavement markings may also be ground-in to reduce the likelihood of a plow catching the edge of the markings to improve their longevity.

The use of green-colored pavement to supplement other bikeway pavement markings, such as a shared lane marking, requires experimental approval from FHWA. Designers should look to IA-14 and FHWA requirements for experimentation when determining if an experimental design is appropriate to consider and feasible to implement.

Figure 6-6: Typical Bike Lane Pavement Markings and Traffic Control Signs



Bicycle Lanes Adjacent to On-Street Parking

Where on-street parking is permitted along a bike lane, the bike lane should be located between the parking lane and the travel lane, unless designed as a separated bike lane following guidance in Section 6.3.7 for separated bike lanes. Delineating the bike lane with two stripes, one along the street side and one along the parking side, is preferable to a single stripe.

When parallel parking lanes are narrow (7 ft.) with high turnover it is preferable to provide a separated bike lane to eliminate conflicts with the vehicles, see Section 6.3.7. When a separated bike lane is not feasible or an interim solution is needed, a buffered bike lane should be provided, see Section 6.3.5. If a striped buffer is not desired, the bike lane width may be increased to provide bicyclists with more operating space to ride out of the area of opening vehicle doors; however, as bike lane widths increase they may appear more like travel lanes and may result in instances of double parking. Designers may consider the use of green pavement to discourage motorists from using the bikeway.

If a buffered bike lane is not feasible, designers should consider the following options in the order stated:

1. Evaluate the reduction of travel lane widths and parking lane widths to accommodate the design widths for buffered bicycle lanes.
2. Evaluate if parking can be consolidated to one side of the street or removed to provide the additional space necessary to accommodate the design widths for buffered bicycle lanes
3. On constrained streets where it is not feasible to eliminate parking or to narrow or remove a travel lane to achieve the minimum dimensions, research indicates there is a slightly reduced risk of dooring in bike lanes as compared to shared lanes.[2] The bicycle lane may be narrowed to a minimum width of 4 ft. to provide a buffer within the door zone area. The door zone buffer may vary from 2 ft. to 4 ft. (3 ft. minimum where parking lanes are 7 ft.). The buffer markings will encourage bicyclists to ride farther from parked vehicles and encourage motorists to park closer to the curb.
4. The minimum combined bicycle lane and parking lane width is 12 ft. All other travel lanes should be narrowed to the allowable constrained width before the minimum combined bicycle and parking lane width is considered. Pavement markings may be used within the bike lane to identify the potential door zone area by extending parking tees or diagonal pavement markings into the bike lane up to 3.5 ft. from the parking lane line. See Figure 6-7.
5. Provide shared lane markings in accordance with Section 6.3.1. This design is unlikely to accommodate the Interested but Concerned Bicyclist, but could accommodate the Highly Confident Bicyclist.

For the scenarios listed above, to improve the visibility of the bike lane adjacent to parking or loading areas, green-colored pavement may be used within the bicycle lane.

Bike lanes should not be placed adjacent to head-in angled parking, since drivers backing out of parking spaces have poor visibility of bicyclists in the bike lane. The use of back-in angled parking can help mitigate the conflicts normally associated with bike lanes adjacent to head-in angled parking. Figure 6-8 provides guidance on the angle, width, and depth of back-in angled parking.

Figure 6-7: Example of Door Zone Markings in Constrained Bike Lane Conditions

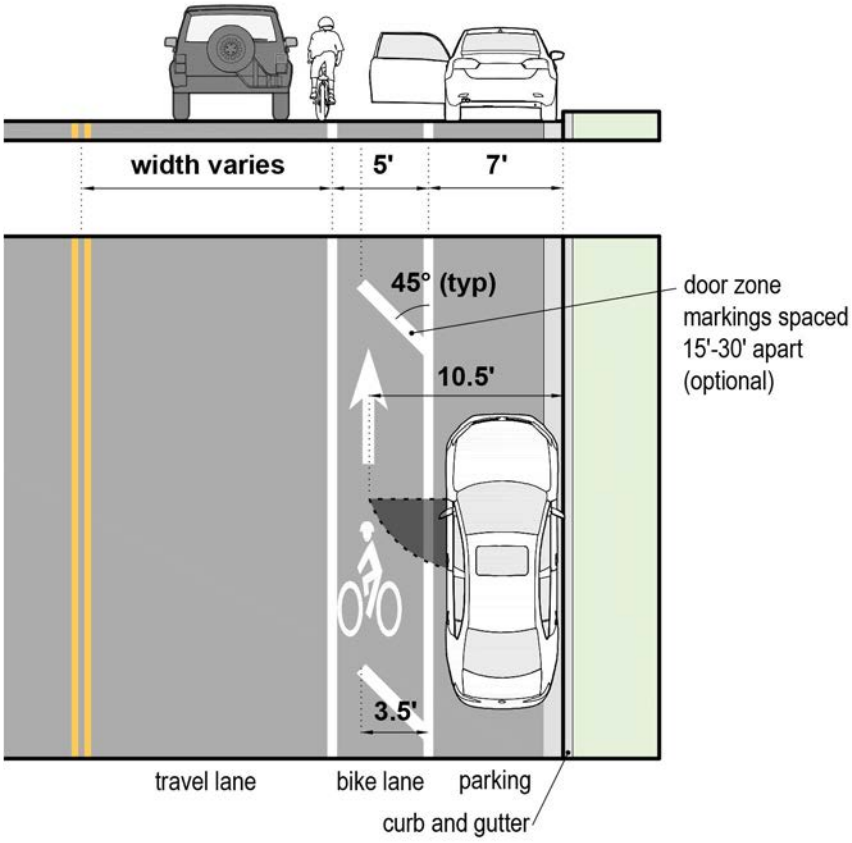
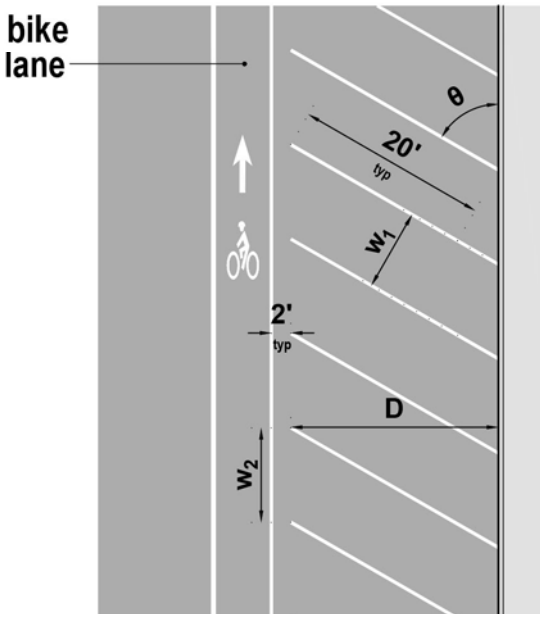


Figure 6-8: Design Criteria for Back-in Angled Parking



Back in Angle Parking			
θ (Degrees)	W_1 (feet)	W_2 (feet)	D (feet)
0˚	7-10	20	7-10
30˚	8-9	16-18	16.9-17.8
45˚	8-9	11.3-12.7	19.8-20.5
60˚	8-9	9.2-10.4	21.3-21.8

W_1 =stall width
W_2 =striping width
D=depth to face of curb
θ=angle

Curbside Management

At locations where vehicles frequently stop or stand in the bike lane, in addition to the signing strategies noted above, it may be beneficial to implement curbside management strategies to result in increased parking and loading space availability during peak periods and to address various curbside uses. Curbside management strategies may include implementation of loading zones, metered parking with performance pricing to promote parking turnover, evening freight delivery, paratransit loading areas, or passenger drop off areas. These strategies may be implemented on a corridor with a bike lane or on adjacent streets. Where on-street parking is present, loading zones may be delineated within the parking lane, and the bike lane may be preserved alongside them. See the *ITE Curbside Management Practitioners Guide* for more information.

6.3.5. Buffered Bicycle Lanes

Buffered Bicycle lanes (buffered bike lanes) are one-way bikeways designated for preferential use by bicyclists that are striped with a buffer space separating the bike lane from the adjacent motor vehicle travel lane and/or on-street parking lane to increase the comfort of bicyclists. Where space is available, existing bike lanes can be improved through the provision of the painted buffer. Buffered bike lanes may be provided on any roadway to increase the comfort of bicyclists and are beneficial for the Interested but Concerned Bicyclist as traffic volumes and speeds increase (see Figure 3-3). Buffered bike lanes follow the same design guidance as bike lanes for widths and other design elements with the following additions:

Width

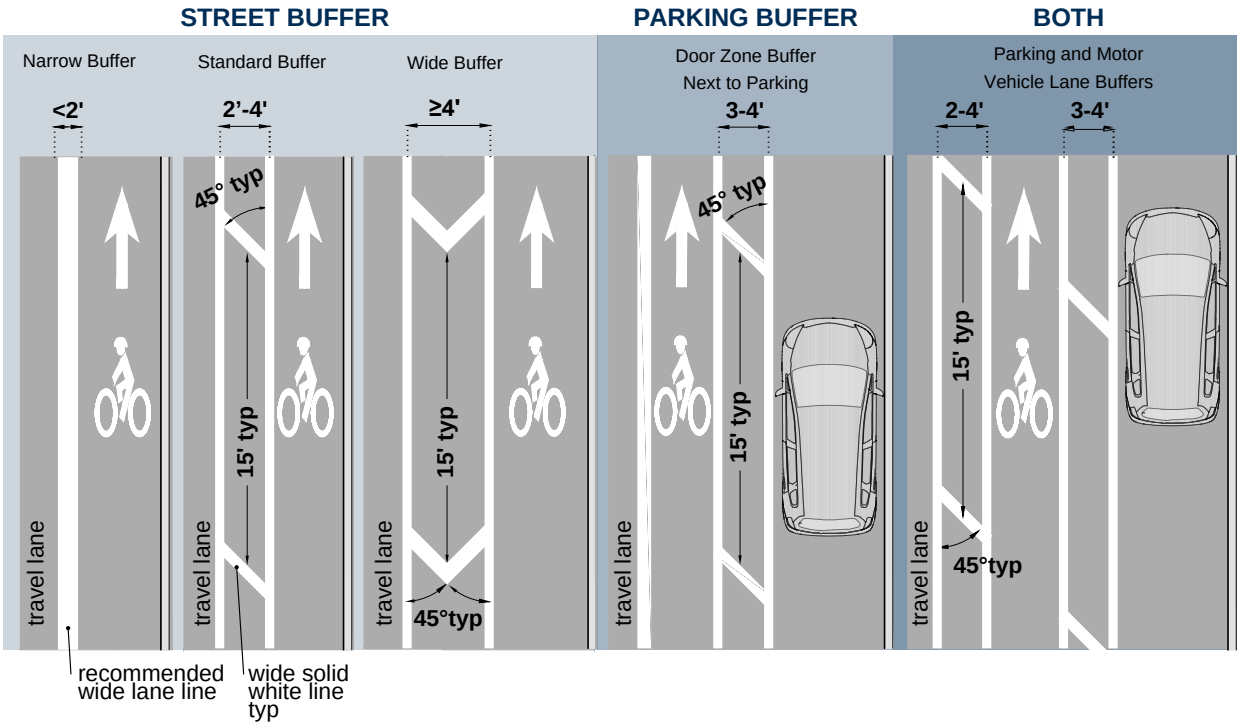
The width of the bike lane should generally follow the guidance for Bicycle Lanes (see Section 6.3.4). However, where a buffered bike lane is provided the bicycle lane may be narrowed to a minimum of 4 ft. to maximize the width of the buffer. While the buffer is not a part of the bicycle lane width, it should be anticipated to be used by bicyclists to pass other bicyclists or to merge into the adjacent travel lane; as such, the buffer surface should be traversable.

Striped Buffer Markings

The striped buffer of a buffered bike lane may include chevrons, diagonal lines, or wide pavement marking stripes depending on the conditions and widths available. See Figure 6-9. Where provided, crosshatching or chevron markings should be provided at a regular interval. A typical spacing is 15 ft. with some locations reduced to as frequent as 5 ft. spacing where engineering judgment determines a more frequent spacing is desirable to discourage motorists encroachment or parking. The maximum spacing should not exceed the equivalent of the speed limit of the roadway (e.g., 45 mph posted speed equals a 45 ft. maximum spacing between markings). There is no maximum buffer width; however, when it is feasible to provide buffers totaling 6 ft. or more in width, consideration should be given to installing separated bike lanes, see Section 6.3.7 for evaluating if a separated bicycle lane may be appropriate.

Where parking is permitted, a buffer located between the bike lane and parking can increase the comfort and safety of bicyclists operating adjacent to parked vehicles by reducing the potential for a dooring type crash. See also Bicycle Lanes Adjacent to On-Street Parking.

Figure 6-9: Typical Striped Buffer Treatments



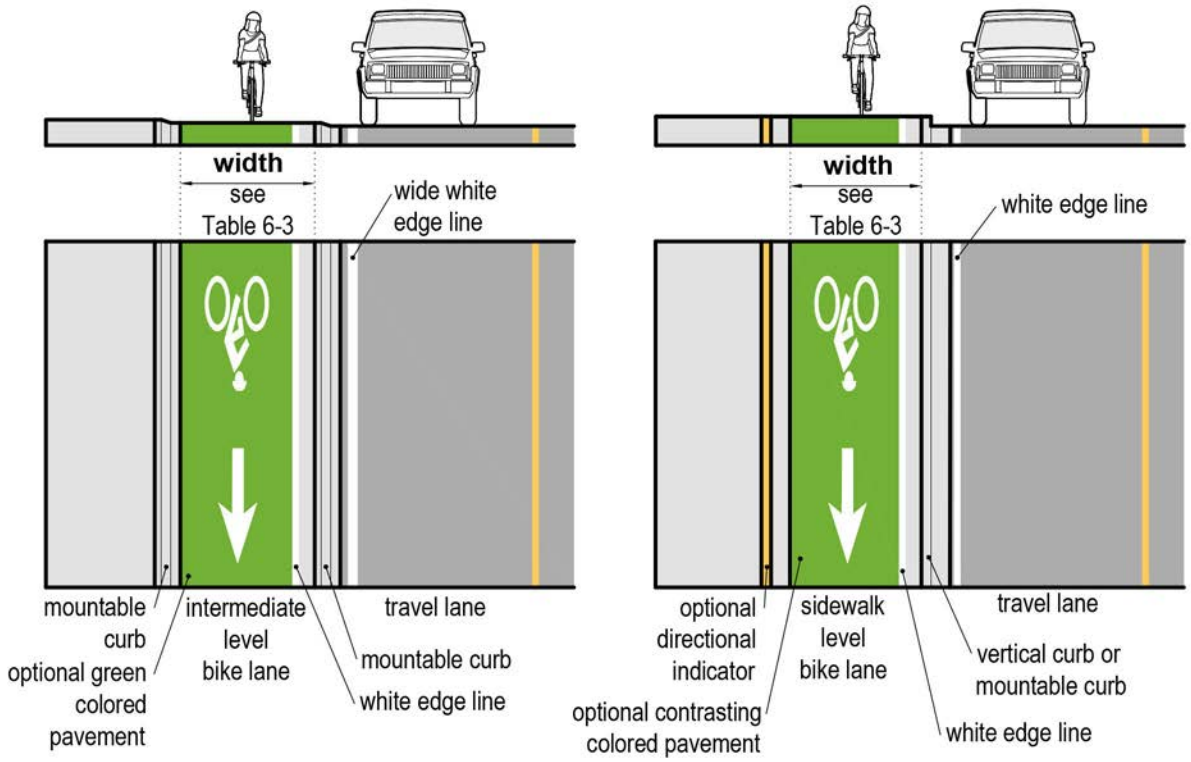
6.3.6. Raised Bicycle Lanes

A conventional bicycle lane can be raised above the street grade to create a new bikeway type that provides more separation from vehicles when a separated bike lane (see Section 6.3.7) with horizontal separation is not feasible. In general, a separated bike lane is preferable to a raised bike lane to prevent motor vehicle encroachment and to reduce the potential for a bicyclist to crash while transitioning from the raised bike lane to the roadway at intersections. While a mountable curb between the raised bike lane and travel lane can reduce crash risk for bicyclists, it may not discourage motorists from encroaching into the raised bike lane. Raised bike lanes should not be installed adjacent to on-street parking due to the greater risk of dooring.

Raised bike lanes can be raised between street level and sidewalk height (intermediate level) or can be located at sidewalk height (sidewalk level). Specific information on the curb types adjacent to raised bike lanes are discussed in Section 6.3.7.

The width of raised bike lanes should accommodate the anticipated bicyclist demand and reduce the likelihood that a bicyclist will have to transition to an adjacent travel lane or sidewalk to pass other bicyclists or to avoid hazards such as debris, surface defects, or objects in the bike lane. The width should also consider the elevation of the bike lane. Table 6-3 provides minimum and constrained widths for both raised bike lane scenarios. A white edge line should be provided near the top of the curb to provide a buffer between bicyclists and the curb; however, the width of the bike lane is still measured from curb to curb.

Figure 6-10: Raised Bike Lane Examples



To prevent motor vehicle encroachment into the bike lane, a sidewalk-level raised bike lane built with a vertical curb between the bike lane and travel lane is preferred. Where sidewalks are adjacent to the raised bike lane, a detectable edge should be provided to reduce the likelihood people with vision disabilities will enter the bike lane. This consideration may lead to the design of an intermediate-level bike lane. Section 6.3.7 provides additional guidance for sidewalk buffer designs.

At locations where an intermediate-level raised bike lane is less than 7 ft. in width, the bike lane should have a continuous mountable curb on both sides, between the bike lane and travel lane and the bike lane and the sidewalk, allowing bicyclists to traverse the curb if necessary (see Figure 6-10). While the provision of a vertical curb along the travel lane is more likely to discourage motorists from entering the raised bike lane, it may also decrease the comfort and safety of bicyclist if the bike lane is not sufficiently wide or if it is necessary for the bicyclist to exit the bike lane.

The bike lane elevation may vary within a single corridor via bicycle transition ramps which raise or lower the bike lane as needed at pedestrian crossings, transit stops, driveways, and intersections. Additional details on the design of intersections are discussed in Section 6.4. Frequent elevation changes along a corridor should be avoided because they reduce the comfort of the bicycling environment and can create maintenance challenges.

Raised bike lanes will require special considerations for maintenance activities as it may be difficult to maintain a debris free surface with standard street maintenance practices. For example, street sweepers cleaning an adjacent travel lane may push additional debris onto an intermediate level bike lane.

Markings and Signing

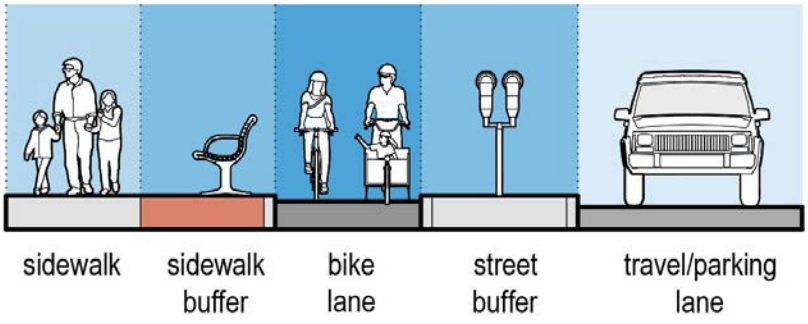
A wide white edge line may be used along a raised bike lane, but it is recommended at locations with an intermediate height bike lane to provide additional emphasis of the mountable curb or the lower height vertical curb. When the sidewalk is attached, directional indicators along the sidewalk should be used to differentiate the bike lane from the sidewalk to pedestrians with low or no vision.

Paving material, green-colored pavement, and signage can all help to differentiate the bike lane from an adjacent travel lane or to increase awareness of the elevation change. Designers may supplement the BIKE LANE (R2-17) sign with a plaque with the message RAISED in black letters.

6.3.7. Separated Bicycle Lanes

Separated bicycle lanes are exclusive bikeways that are physically separated from motor vehicle traffic. While buffered bike lanes provide a horizontal separation from motor vehicle traffic, separated bike lanes also provide vertical separation such as flexible delineators or a curbed median. Separated bike lanes may be located at street elevation, sidewalk elevation, or at an intermediate elevation in between the sidewalk and street. When built at sidewalk level, care must be taken to ensure they are distinct from the sidewalk to discourage pedestrian encroachment. Separated bike lanes may be installed in one-way and two-way configurations, each of which present opportunities and challenges that must be considered during the design process.

Figure 6-11: Separated Bike Lane Zones



Separated bicycle lanes are more appealing to a wider range of bicyclists than other bike lanes when installed along higher volume and faster speed roads. They also prevent motor vehicles from driving, stopping or waiting in the bikeway and provide greater comfort to pedestrians than a shared use path by separating them from bicyclists.

Separated bike lanes are comprised of three distinct zones:

1. Bike lane – The bike lane is the space in which the bicyclist operates. It is located between the street buffer and the sidewalk buffer.

2. Street buffer – The street buffer physically separates the bicycle lane from a vehicle lane or on-street parking both vertically and horizontally.
3. Sidewalk buffer – A sidewalk buffer separates the bike lane and sidewalk zones.

Within the bike lane zone, the horizontal and vertical alignment of the bike lane should be smooth. Bicyclists should not need to climb sudden steep inclines, nor should they be forced to veer sharply from side to side to stay in the bike lane. Horizontal tapers should follow the same equation provided for on-street striped bicycle lanes (see Section 3.6.3).

Width

Separated bike lane width should be selected based on the desired elevation of the bike lane, adjacent curb type(s), anticipated volume of users, likelihood of passing maneuvers, and one-way vs. two-way operation. Bicyclists typically do not have the option to pass each other by moving out of a separated bike lane as they would in a standard bike lane because of the vertical elements between the bikeway and motor vehicle travel lane. It is therefore preferable for the width of the separated bike lane to accommodate passing and potentially permit side-by-side bicycling.

The minimum bike lane widths for one-way and two-way separated bike lane(s) are provided in Table 6-4 and Table 6-5 respectively based on the anticipated directional bicyclist volumes. The widths vary depending on adjacent curb types and account for shy distances to these different curb types. Similar to conventional bike lanes, the widths in these tables should be measured from the relevant edge of the bike lane striping, face of curb, or edge of the gutter pan.

Table 6-4: Minimum One-Way Separated Bike Lane Widths

Peak Hour Directional Bicyclist Volume	One-Way Separated Bike Lane Width (ft)		
	Between Vertical Curbs	Adjacent to One Vertical Curb	Between Sloped Curb or at Sidewalk Level
<150	6.5 - 8.5	6 - 8	5.5 - 7.5
150-750	8.5 - 10	8 - 9.5	7.5 - 9
>750	≥10	≥9.5	≥9
Constrained Condition*	4.5	4	3.5

*Peak Hour Directional Bicyclist Volume not applicable

Table 6-5: Minimum Two-Way Separated Bike Lane Widths

Peak Hour Directional Bicyclist Volume	Preferable Two-Way Bike Lane Width (ft)		
	Between Vertical Curbs	Adjacent to One Vertical Curb	Between Sloped Curb or at Sidewalk Level
<150	10 - 12	9.5 - 11.5	9 - 11
150-350	12 - 16	11.5 - 15.5	11 - 15
>350	≥16	≥15.5	≥15
Constrained Condition*	8.5	8	7.5

*Peak Hour Directional Bicyclist Volume not applicable

Curbing

Some curb types can increase the risk of bicycle crashes if struck by a wheel or pedal. The face of curb angle—vertical, sloping, or mountable (see SCD BP 5.1)—and curb height influence the functional width of the bikeway, crash risk to bicyclists, the ability to exit bikeways to access bike parking or adjacent properties, pedestrian detectability, and the risk of encroachment into the bikeway by motorists. The following curb types are recommended for separated bicycle lanes:

- Curb Type 10-A, Sloping Curbs are preferred along any separated bike lane to reduce pedal strike hazards and to ease access to the sidewalk. See Table 6-4 and Table 6-5 for bike lane widths were sloping curbs should be provided.
- Curb Type 10-B, Mountable curbs are traversable by bicyclists, reduce pedal strike hazards, and are preferred along intermediate level separated bicycle lanes.

In general, any curb type with a height of 3 inches or less will allow a bicyclist to ride closer to the curb without fear of a pedal strike. Curb Type 10-A and 10-B may be adjusted based on site conditions but must be at least 2 inches to be detectable by people who are blind.

Curbs with integral gutters result in a longitudinal seam parallel to bicycle travel that may deteriorate, resulting in dips or ridges that increase crash risk for bicyclists. Similar to conventional bike lanes, gutters should not be included in the bike lane width of a separated bike lane. For retrofit projects where separated bike lanes are added to existing roadways, integral gutters may not be avoidable; however, for new roadways or roadway reconstruction projects, integral gutters should not be provided along a separated bike lane.

One-Way vs. Two-Way Operation

Designers must determine if it would be more appropriate to place a one-way separated bike lane on each side of the street, or to place a two-way separated bike lane or side path on one side of the street (and if so, which side) or on both sides of the street. Note that side paths are a type of shared use path and therefore generally discussed in Chapter 5; however, at intersections, their geometric and operational design considerations closely follow those for separated bike lanes and are discussed here as applicable. Selecting the appropriate configuration requires an assessment of many factors, including safety, overall connectivity, ease of access, public feedback, available right-of-way, curbside lane uses, intersection operations, ingress and egress to the bikeway, maintenance, and feasibility. The analysis should also consider benefits and trade-offs to people bicycling, walking, taking transit, and driving. The primary objectives for determining the appropriate configuration are to

- provide clear and intuitive transitions to existing or planned links of the bicycle network;
- minimize conflicts between all users – bicyclists, pedestrians, and motorists; and to
- provide convenient access to destinations.

One-way separated bike lanes in the direction of motorized travel are typically the easiest option to integrate into the existing operation of a roadway and are the preferred design in most situations. This configuration provides intuitive and direct connections with the surrounding transportation network, including simpler transitions to existing bike lanes and shared travel lanes. It is also the design most consistent with driver expectation since bicyclist operation is in the same direction as motor vehicle operation.

Two-way separated bike lanes or a side path on one side of a street introduces a counter flow movement for bicyclists, which can be challenging – but not impossible – to accommodate. Two-way separated bike lanes might be appropriate where key destinations exist along one side of the road, where driveways and intersections are sparse along one side of the road but frequent along the other side, or for other context-based reasons. If used, care should be given to the design of intersections, driveways, and other conflict points, as people walking and driving may not anticipate bicyclists traveling in the opposite direction (See Section 6.3.8 and Section 8.4.5). Motorists entering the roadway and needing to cross the separated bike lane often will not notice bicyclists approaching from their right and motorists turning from the roadway across the bikeway may likewise fail to notice bicyclists traveling from the opposite direction. At the terminus of the bikeway, the counter flow bicyclist must also be clearly transitioned back into traffic lanes or to a different bikeway type.

If all other factors are equal (number of conflict points, right-of-way availability, predictability, etc.), consider locating bikeways on the north side of urban roadways to reduce shading snow and ice during winter months.

Two-way separated bike lanes or a side path on both sides of a street introduces the same challenges noted above but may be appropriate on roadways with fewer crossing opportunities for bicyclists. The two-way operation on both sides of the street can allow bicyclists to make more direct connections to adjacent land uses and may prevent wrong way riding that might otherwise occur on some one-way separated bike lanes.

For selecting the location of one-way or two-way bikeways on one-way or two-way roadways, designers should understand the following principles:

- Whenever possible, bikeways should be designed to operate as one-way in the direction of adjacent motor vehicle traffic, to reduce the amount of information that motorists and pedestrians will need to make decisions about safe movements. Research indicates that two-way operation resulted in a higher crash rate than one-way operation.[3]
- Where separated bicycle lanes are built on one-way streets, it is preferable to place them on the right side.[4] Where bikeways need to be installed on the left, additional treatments to increase awareness and visibility should be considered.
- If bikeways are built on the left side of a one-way street, crashes may increase in the short term, as motorists and bicyclists become accustomed to interacting on the left side, but should normalize over time.[5] There are cases (such as on high-frequency bus routes) where it may be recommended to install the bikeway on the left side of the one-way street. In those cases, designers should consider additional treatments to increase awareness and visibility, easing the transition to the bikeway for motorists and bicyclists.

Table 6-6 and Table 6-7 summarize the separated bike lane configurations for one-way and two-way roadways, along with a discussion of associated issues and considerations.

Table 6-6: Separated Bike Lane Configurations on a One-Way Street

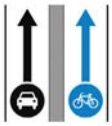
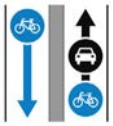
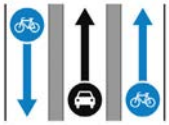
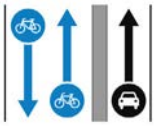
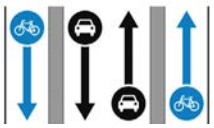
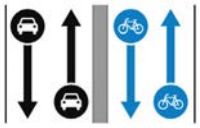
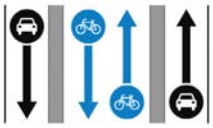
Corridor-level Planning Considerations	One-way SBL	Counterflow SBL	One-way SBL Plus Counterflow SBL	Two-way SBL
				
Access to Destinations	Limited access to other side of street		Full access to both sides of street	Limited access to other side of street
Network Connectivity	Does not address demand for counterflow bicycling, may result in wrong way riding	Requires bicyclists traveling in the direction of traffic to share the lane (may result in wrong way riding in the SBL); counterflow progression through signals may be less efficient	Accommodates two-way bicycle travel, but counterflow progression through signals may be less efficient	
Crash Risk	Lower because pedestrians and turning drivers expect concurrent bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic		
Intersection Operations	May use existing signal phases; separate bicycle phase may be required depending on vehicle volumes	Typically requires additional signal equipment; separate bicycle phase may be required depending on vehicle volumes		

Table 6-7: Separated Bike Lane Configurations on a Two-Way Street

Corridor-level Planning Considerations	One-way SBL Pair	Two-way SBL	Median Two-way SBL
			
Access to Destinations	Full access to both sides of street	Limited access to other side of street	Limited access to both sides of street
Network Connectivity	Accommodates two-way bicycle travel		
Crash Risk	Lower because pedestrians and turning drivers expect concurrent bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic	Higher because pedestrians and turning drivers may not expect counterflow bicycle traffic, but median location may improve visibility and create opportunities to separate conflicts
Intersection Operations	May use existing signal phases; separate bicycle phase may be required depending on vehicle volumes	Typically requires additional signal equipment; separate bicycle phase may be required depending on vehicle volumes	

Street Buffer

Street buffer width is a central element in separated bike lanes and side path design. Appropriate street buffer widths vary depending on the degree of separation desired, right-of-way constraints, and the types of vertical elements, features, or uses that must be accommodated within the buffer. In general, the minimum width of a street buffer is at least 6 ft., regardless of the type of street buffer. Street buffers may be narrowed to a minimum of 2 ft. (3 ft. encouraged when on-street parking is present) in constrained conditions or where bicyclists and turning motorists are phase separated at a signalized intersection.

In addition to providing increased physical separation mid-block, street buffers impact bicyclists' safety at intersections, driveways, and alley crossings. Street buffer widths that provide a recessed crossing between 6 ft. and 16.5 ft. from the motor vehicle travel lane have been shown to reduce crashes at uncontrolled separated bike lanes and side path crossings (See Figure 6-30).[6, 7] This offset improves visibility between bicyclists and motorists who are turning across their path, and creates space for motorists to yield (this is discussed in more detail in Section 6.5.2).

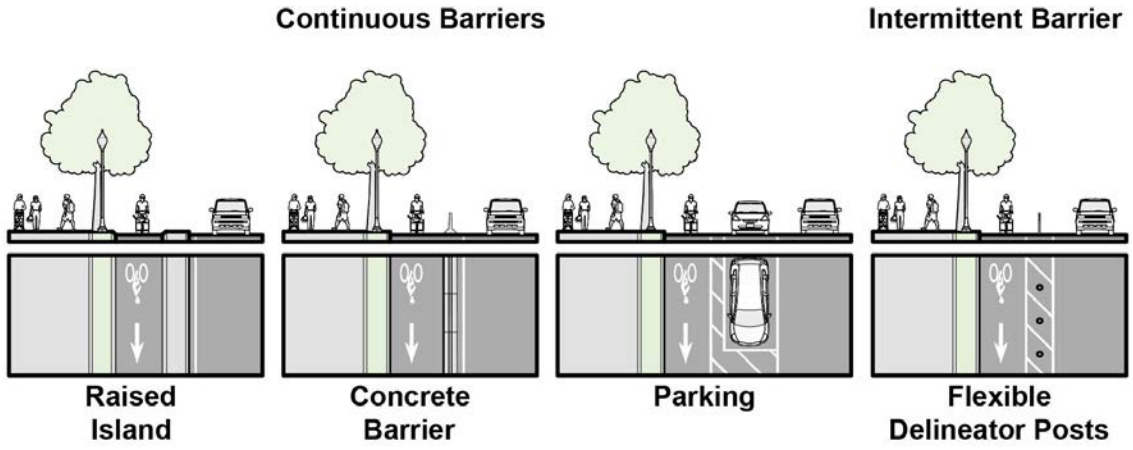
Continuous or intermittent vertical elements are needed in the street buffer to provide separation between motor vehicle traffic and the bikeway operating zone. For new roadways and reconstruction projects, these vertical elements will typically be curbed medians. Depending on the available buffer width, it may also be possible to implement green infrastructure strategies such

as linear bioretention cells within the buffered area; see L&D Manual Volume 2 for stormwater design. Existing or future street sweepers and snowplows should be able to access the bikeway. If the bikeway clear space widths are not able to accommodate the equipment, the vertical elements should be mountable or designed so that both the vertical elements and the maintenance equipment is not damaged.

For retrofit projects where separated bike lanes are being added to existing roadways, the street buffer typically consists of buffered bike lane pavement markings (see Section 6.3.5) and are supplemented with vertical elements. On lower speed roads (30mph or less), flexible delineator posts, concrete barriers, or other vertical elements (see Figure 6-12) can be used. On higher speed roads, vertical elements must be crashworthy. Vertical objects may be struck by motor vehicles and require regular replacement. Maintenance and operation crews should plan on replacing vertical objects placed in the buffer zone and refreshing pavement markings, on a regular basis. If vertical objects are struck with significant regularity, adjustments to the design should be considered. The placement of vertical elements within the street buffer should consider the need for shy distances to the bikeway and to the travel lane, access to and from on-street parking, drainage, and maintenance. Vertical element spacing should consider the alignment with corresponding pavement markings in the buffer and the necessary effectiveness of the vertical elements to keep vehicles from encroaching into the separated bike lane. For example, on a higher-speed suburban road where motorists are less likely to cross into the bike lane (i.e., fewer driveways or loading and unloading needs), a wider spacing of the vertical elements may be acceptable, but on lower-speed urban streets, a spacing of 15 ft. or closer may be appropriate to prevent vehicles from attempting to stop or park in the bike lane, similar to the recommended design for buffered bike lane markings. Vertical elements may also be more closely spaced approaching intersections or driveways to better see where the gaps in the vertical elements are provided for driveway access points while preventing vehicle encroachment too early at these conflict points.

On-street parking may be used as a street buffer without other vertical elements if the parking always has high occupancy throughout the day and night, but vertical objects are typically provided to prevent vehicles from parking within the street buffer or bike lane. Additional pedestrian accessibility considerations for on-street parking are identified in the sections below.

Figure 6-12: Vertical Elements in the Street Buffer Zone



Sidewalk Buffer

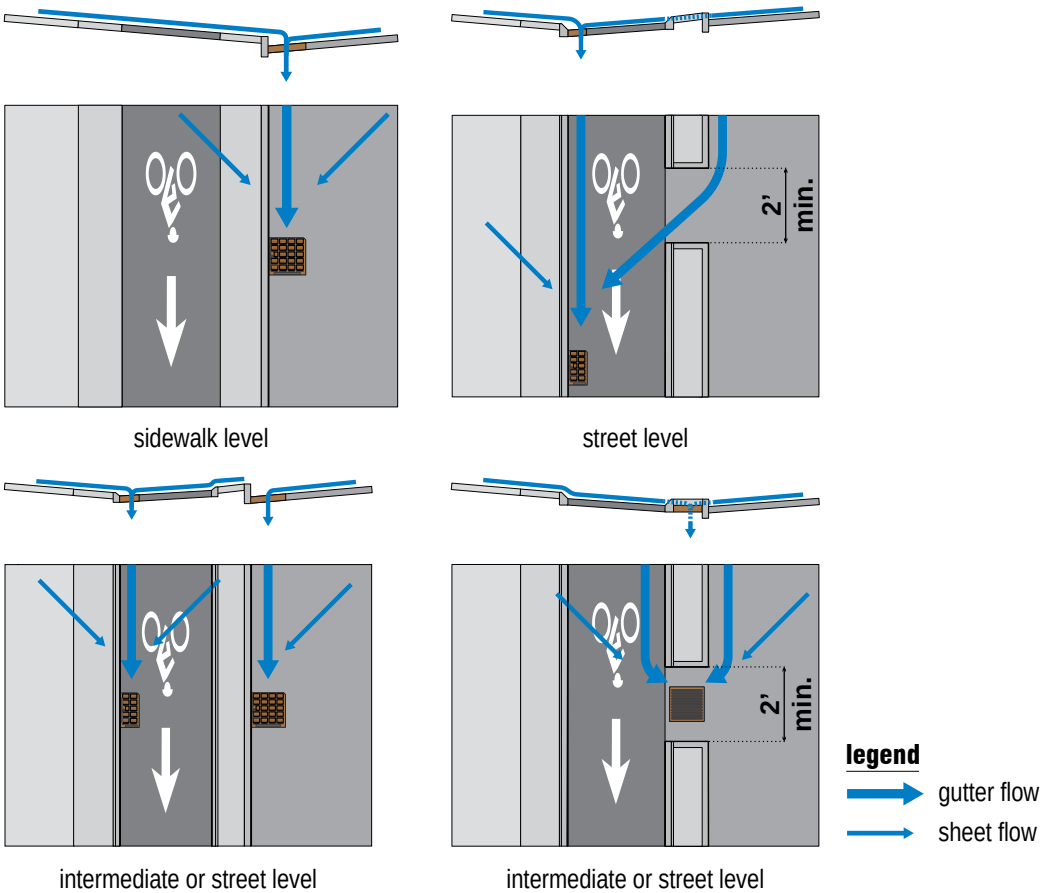
The sidewalk buffer zone separates the sidewalk from the separated bike lane to communicate that the sidewalk and the separated bike lane are distinct spaces. Sidewalk buffer widths may vary depending on context (See Chapter 4). When a separated bike lane is raised to sidewalk level, sidewalk buffers need to include a delectable edge so pedestrians with vision disabilities can distinguish between the bike lane and the sidewalk. See Chapter 4 for detectable edge design options.

Vegetation in the sidewalk buffer should be trimmed and maintained on a regular basis to keep the bikeway clear at all times.

Drainage

For retrofit projects, most vertical elements are non-continuous or can be provided with gaps or drainage channels to allow stormwater to flow through the street buffer. This approach allows drainage patterns to remain largely unchanged from existing conditions and allows stormwater to reach existing catch basins. When some continuous vertical elements are introduced along separated bike lanes, this may impact existing drainage patterns and require alterations to a drainage system. Some example separated bike lane drainage patterns are shown in Figure 6-13. In some suburban and rural areas, the preferred practice is to direct runoff onto adjacent vegetated areas, where soils and slopes allow for runoff to be conveyed or infiltrated.

Figure 6-13: Examples of Separated Bike Lane Drainage Configurations



Maintenance

Maintenance of separated bike lanes should be discussed early in the design process to ensure that the bike lane will be maintained to provide safe operation for bicyclists. This often requires a discussion of existing street cleaning equipment and snow clearing equipment to understand the width needed to accommodate maintenance operations. Although a city or district may not have a typical plow or street sweeper narrow enough to get into a separated bike lane, there may be other existing equipment that can be used, such as a loader, tractor, or utility vehicle. The purchase of new equipment may also be appropriate, particularly as a bike network expands, to ensure that the equipment is appropriate for maintaining the bikeway type(s).

The consideration of maintenance may be the justification for providing a wider bike lane or locating vertical elements closer to the travel lanes to allow equipment to pass behind the vertical elements to sweep or plow the bike lane. Similarly, the justification for a two-way separated bike lane may be the ability to more easily sweep and plow the bike lane. Additional discussion of maintenance is provided in Chapter 12.

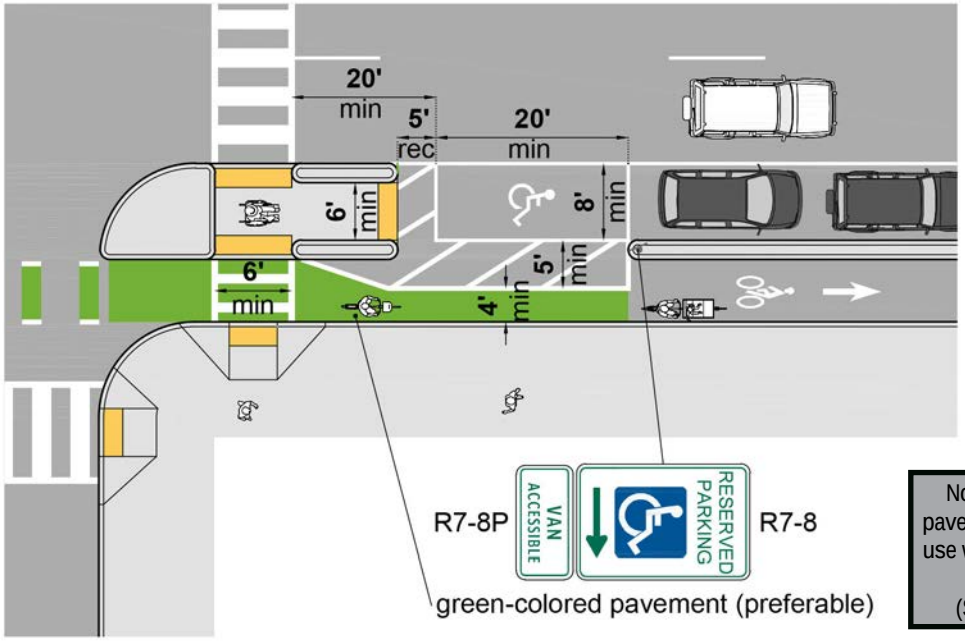
Accessible Parking and Loading Zones Adjacent to Separated Bicycle Lanes

Accessible parking and loading spaces require additional space adjacent to parking stalls for vans with ramps to allow passenger boarding and alighting, and to ensure an accessible route is provided to and from the sidewalk. This can present a unique challenge when separated bike lanes are present between the on-street parking and sidewalk.

Pedestrian accessibility guidelines define circumstances and minimum number of accessible on-street parking spaces that should be provided within a block perimeter where marked or metered on-street parking is provided. See PROWAG Section R214. In general, accessible parking is required on each block face, so accommodating accessible parking on cross streets where separated bike lanes are not present is preferred. However, where accessible parking is appropriate on a street with separated bike lanes, it may be provided close to intersections or mid-block.

When accessible parking or loading is provided close to intersections, the design should allow the intersection curb ramps to also serve as the accessible route for the parking space(s), see Figure 6-14. When accessible parking is provided mid-block, a separate curb ramp will be necessary to provide an accessible route, see Figure 6-15. In constrained locations where accessible parking is provided, the protected bike lane may be narrowed to a minimum constrained width adjacent to the parking. At locations without on-street parking but where an accessible parking or loading area is desired, a lateral deflection (bend-out) of the separated bike lane will often be required to accommodate the accessible space. Bike lane deflection should occur gradually but should not exceed the shifting taper guidelines to maintain bicyclist safety and comfort (See Section 3.6.3).

Figure 6-14: Example of Accessible On-Street Parking at Intersection



Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

alternative option:

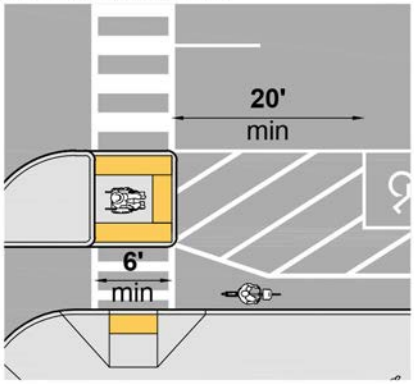
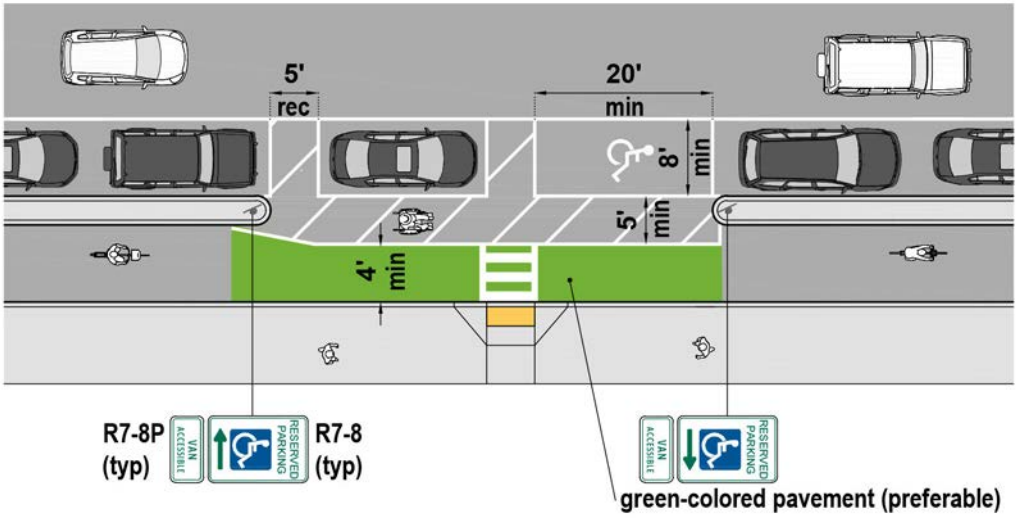


Figure 6-15: Example of Accessible Mid-block On-Street Parking



Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

At locations where there is a higher volume of pedestrians crossing between the separated bike lane such as valets or designated rideshare pick up and drop off, the following treatments should be used:

- Add a PED XING pavement marking across the bike lane where the approach grade is 3 percent or greater, or where the location is within 100 ft. of an intersection.
- Use a raised street buffer and sidewalk or intermediate-level separated bicycle lane.
- Increase the street buffer width. This may result in narrowing the bike lane width to constrained bike lane widths along this short segment.
- Mark pedestrian crossings and use BIKES YIELD TO PEDS (R9-6) signs.
- Pedestrian railings may be used along the bikeway to direct pedestrians to marked crossings of the bike lane at loading zones where pedestrian activity is anticipated to be high. When present, these should be placed at an appropriate offset so that they do not present a hazard to bicyclists (see discussion on Shy Spaces in Section 3.6.2).

Transitions between Separated Bicycle Lanes and other Bikeway Types

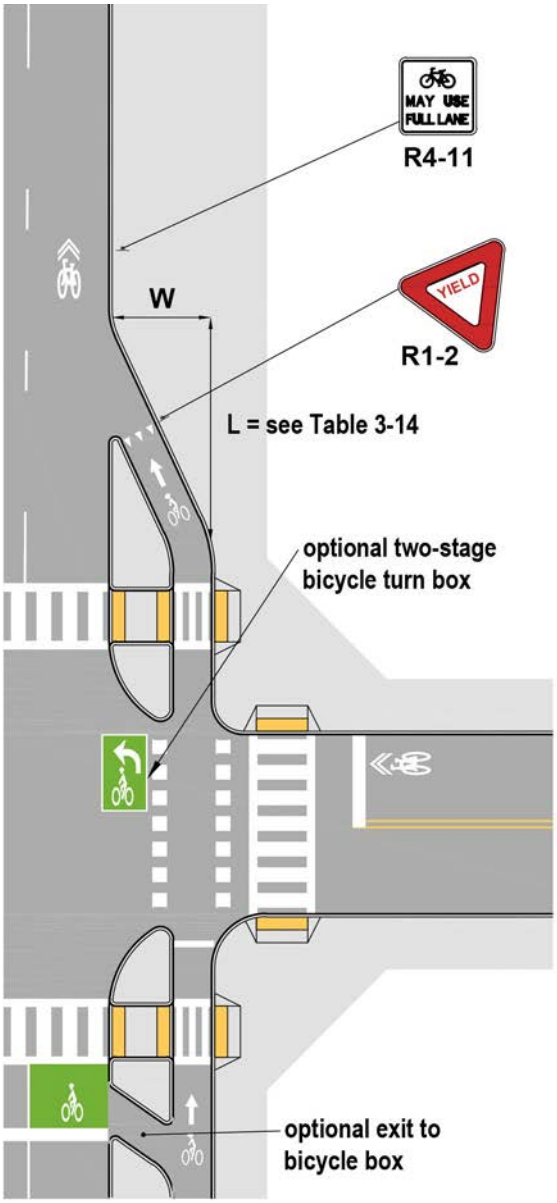
Transitions between separated bike lanes and other bikeway types is essential for all projects that include a separated bike lane. The actual transition design can vary greatly from location to location depending on many of the contextual factors discussed throughout this guide. The selected transition design should clearly communicate how bicyclists should enter and exit the separated bike lane in order to minimize conflicts with other users.

Transitions of two-way separated bike lanes to bikeways or shared lanes that require one-way bicycle operation require additional considerations. Bicyclists operating in the counter flow direction will be required to cross at least two directions of travel and potentially two or more roadways. Failure to provide a clear transition to the desired one-way operation may result in wrong way bicycle riding. The principles identified for intersection design in Section 6.5.1 should be followed.

The use of directional, tapered islands can provide positive direction for bicyclists to follow the desired transition route. It may also be desirable to use green-colored pavement within intersection crossings (see Section 6.3.4) and bike boxes and two-stage bicycle turn boxes (see Section 6.5.1) to improve legibility and provide strong visual guidance of the intended path across and through an intersection to all users. The crossing may warrant bicycle signals at signalized crossings (see Section 8.4)

Figure 6-16. through Figure 6-21. provide illustrations of some example transitions.

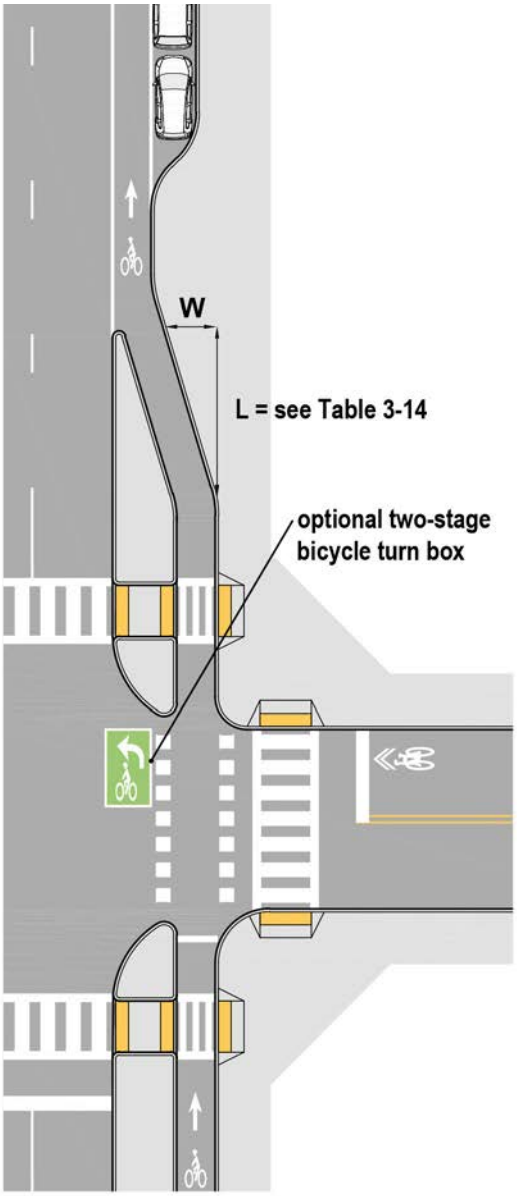
Figure 6-16: Transition to Shared Lane



Note: Bicycle Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

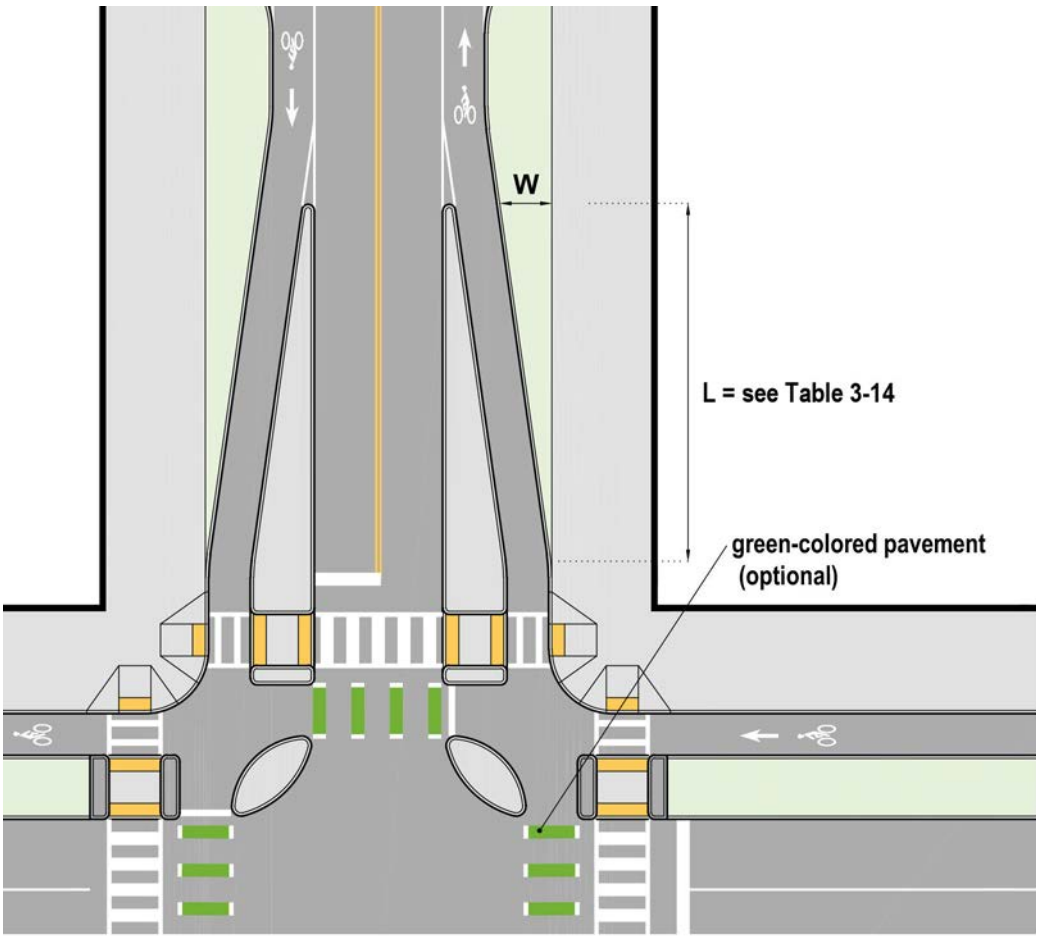
Note: Two-Stage Bicycle Turn Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

Figure 6-17: Transition to Conventional Bike Lane



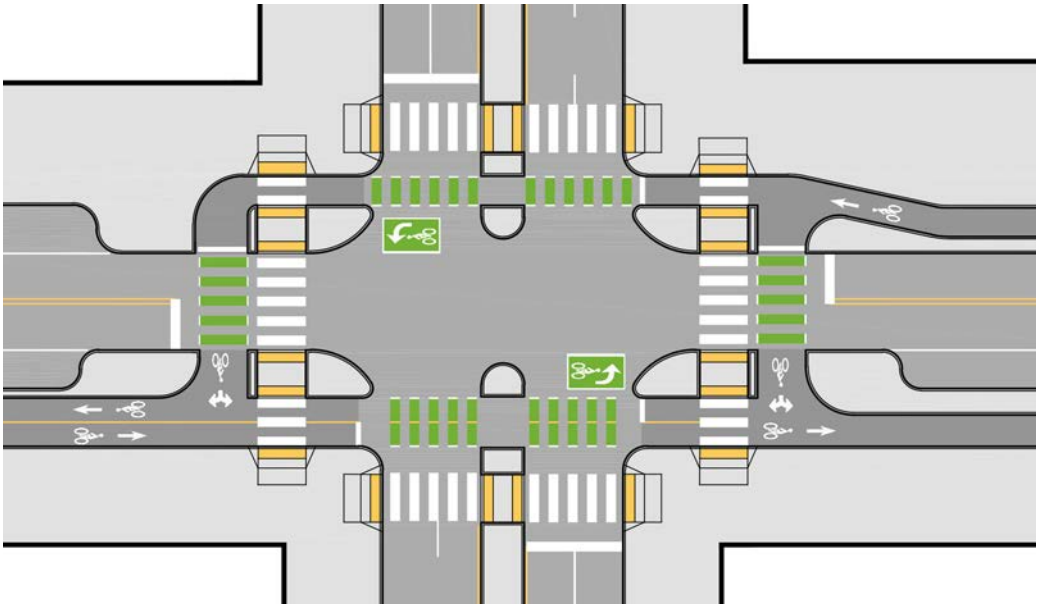
Note: Two-Stage Bicycle Turn Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

Figure 6-18: Transition to Conventional Bike Lane on Intersecting Street



Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA.
(See Section 1.2.2)

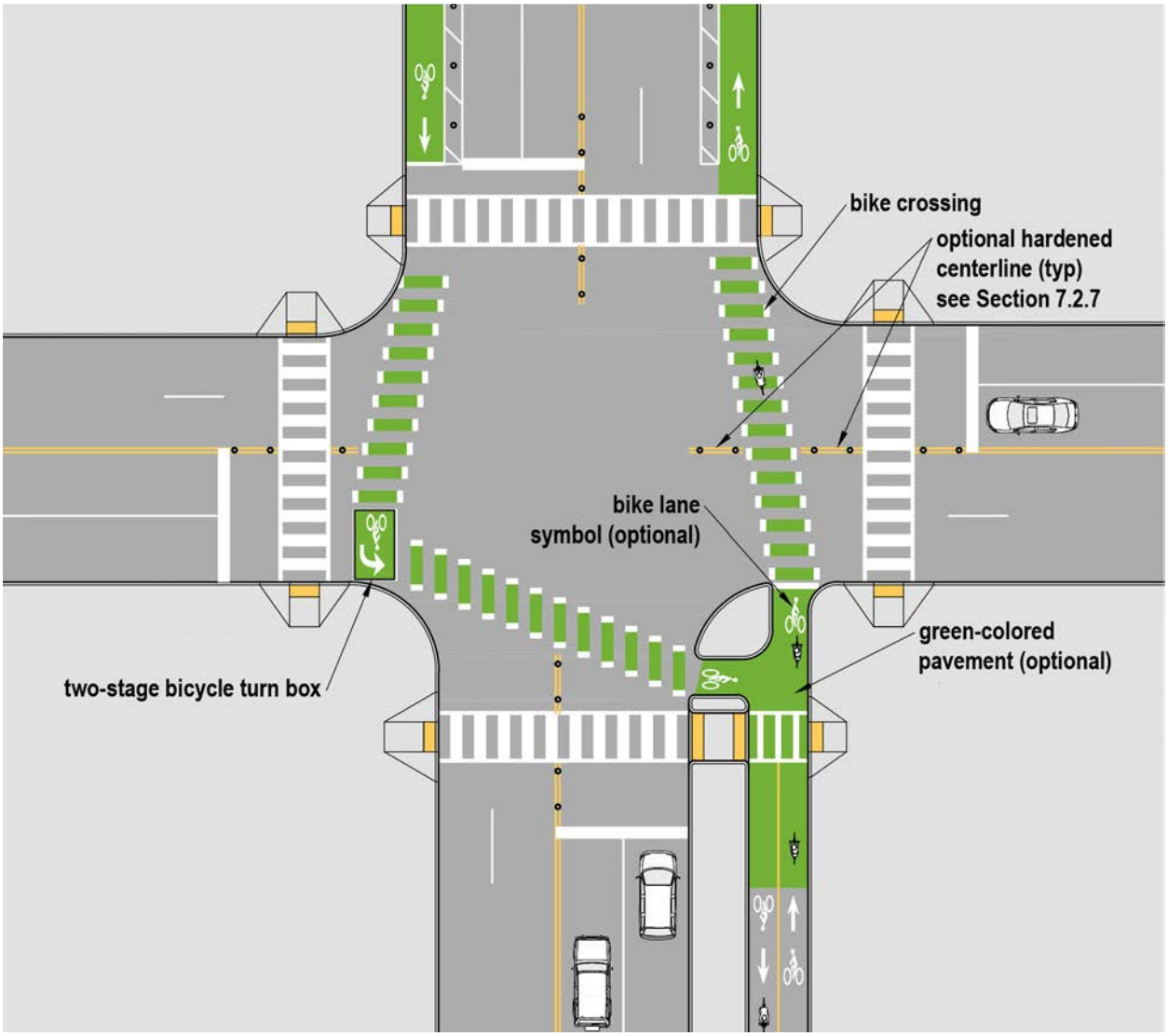
Figure 6-19: Transition from One-Way to Two-Way Separated Bike Lanes at Protected Intersection



Note: Two-Stage Bicycle Turn Boxes are permitted for use with Interim Approval from FHWA.
(See Section 1.2.2)

Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA.
(See Section 1.2.2)

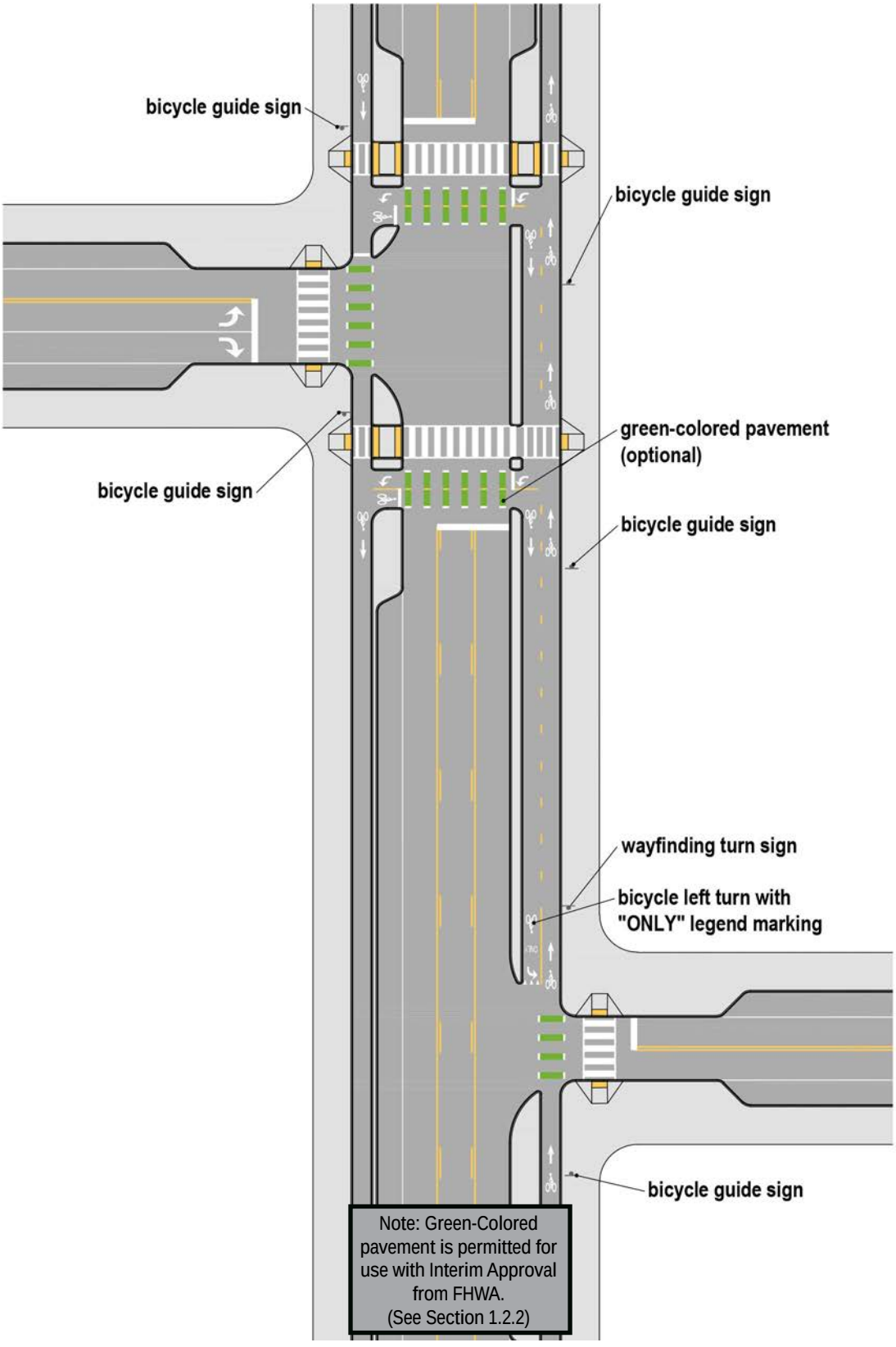
Figure 6-20: Transition from One-Way to Two-Way Separated Bike Lanes with Two-Stage Turn Box


bike crossing
optional hardened centerline (typ) see Section 7.2.7
bike lane symbol (optional)
green-colored pavement (optional)
two-stage bicycle turn box

Note: Two-Stage Bicycle Turn Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

Figure 6-21: Transitions between Offset Intersections with Two-Way Separated Bike Lanes


bicycle guide sign
bicycle guide sign
green-colored pavement (optional)
bicycle guide sign
bicycle guide sign
wayfinding turn sign
bicycle left turn with "ONLY" legend marking
bicycle guide sign
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

6.3.8. Bicycle Ramps

Bike ramps are used to improve bicyclist safety or comfort, to shift the elevation of a bikeway to a different elevation (e.g., from street-level to sidewalk-level), or to change the bicycle facility type (e.g., from a conventional bike lane to side path).

It is common to use bike ramps when approaching roundabouts, at interchange ramp crossings, or at high-conflict zones (such as heavy weaving areas or high turning volume intersections). In these situations, the bike ramp serves the purpose of allowing bicyclists to avoid sharing travel lanes with motorists. In some instances, it may be appropriate to provide a bike ramp that would be used by most bicyclists, but also provide an on-street option for Highly Confident and Somewhat Confident Bicyclists to allow them to ride in the shared lane environment.

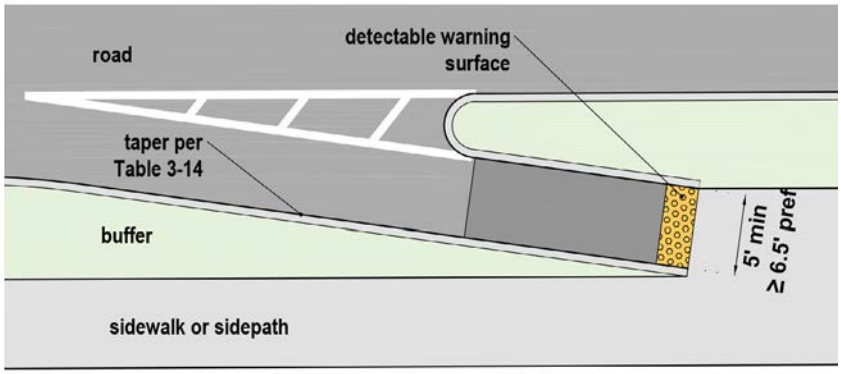
The other situation to use a bike ramp is approaching pedestrian conflict areas or raised crossings across a separated bike lane, where a change in elevation is desired to meet pedestrian accessibility guidelines, to slow bicyclists at conflicts, or to transition the bikeway elevation.

In either situation, the overall facility geometry, the extent of construction or type of project, or the types of bikeways being connected can affect the alignment of the bike ramp. Figure 6-22 identifies two options for bike ramps that transition to a shared use path. Detail 1 is preferable to provide a bicyclist with a comfortable change in alignment and ensure grade breaks are parallel to the path of travel. Detail 2 should be used where there is insufficient space to provide the straight taper shown in Detail 1. Designers may encounter the following challenges with the design shown in Detail 2:

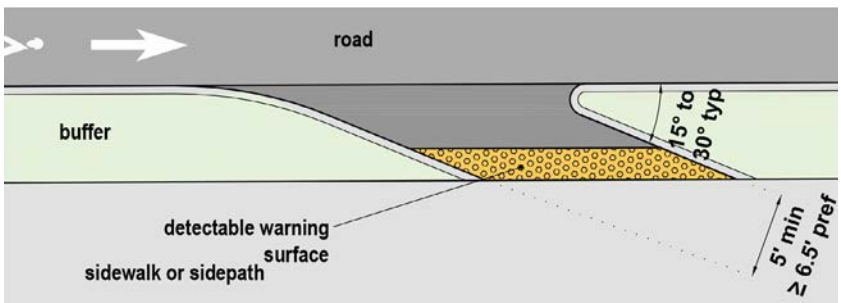
- Narrow bike ramp widths can force bicyclists to encroach on adjacent motorist travel lanes, pedestrian zones, or on-coming bicycle traffic on two-way facilities in order to access the ramp.
- If grade breaks at the top and bottom of the bike ramp are not perpendicular to the bicyclist path of travel, bicyclists with more than two wheels (e.g., adult tricycles or bikes with trailers) can experience instability or overturning.

In both situations, increasing the width of the bike ramp can help to address these issues.

Figure 6-22: Bicycle Ramp to Shared Use Path or Sidewalk



Detail 1 - preferred bicycle ramp with detectable warning



Detail 2 - lateral shift bicycle ramp with detectable warning

Bike ramps are intended for the exclusive use of bicyclists and therefore the slopes need not comply with pedestrian accessibility guidelines. Ramp grades can be steeper than pedestrian curb ramps; however, grades of 5 to 8 percent can help to address issues of comfort when transitioning from one elevation to another. Where a bike ramp connects directly into a sidewalk or shared use path, a detectable warning surface shall be used at the top of the bike ramp, and may be supplemented with a directional indicator to guide pedestrians away from the bike ramp (see Section 4.3.3).

6.3.9. Bicycle and Micromobility Parking

When bikeways are provided along a corridor, bicycle parking should be included along the corridor and opportunities to accommodate bikeshare systems and other shared micromobility systems will increase. The placement of these bike parking and micromobility systems should be considered as part of any street design, particularly in regard to maintaining pedestrian accessibility on sidewalks. Without the provision of dedicated parking areas, bicycles and other micromobility vehicles have the potential to obstruct access. This section focuses only on short-term bike parking considerations. See the APBP *Bicycle Parking Guidelines* for additional bike parking considerations, including long-term bike parking.

As discussed previously, the sidewalk is made up of three zones: Pedestrian Through Zone (Pedestrian Access Route), Frontage Zone, and Buffer Zone. The buffer zone typically serves a wide range of amenities such as landscaping, street lighting, signage, benches, and traffic control devices. Another common use of this space is to provide bike racks or dedicated areas for bicycle and micromobility storage. These areas can be for personal vehicles or for shared fleet vehicles for municipal or regional bike and scooter share programs.

When bicycle or e-scooter parking is provided in the sidewalk buffer zone, it should generally not encroach into the pedestrian through zone unless an unobstructed path of travel for pedestrians is maintained as discussed in Chapter 4. Designers should follow the general design guidance provided below and defer to local or regional agency policies where applicable.

- Select racks that are versatile and intuitive, allowing bicycles of all shapes and sizes to be locked through the frame and at least one wheel. See Figure 6-23 for examples of typical recommended bike racks and those that are not recommended.
- A 5 ft. minimum clear pedestrian access route must be maintained behind any designated bike parking or designated dockless mobility parking area. In high-volume pedestrian areas, the unobstructed pedestrian through zone should match the widths discussed in Chapter 4.

Figure 6-23: Recommended and Not Recommended Bike Racks

- A minimum depth of 6 ft. for bicycle parking and bikeshare docks and 5 ft. for scooter zones should be provided. Additional space to accommodate longer bicycles should be considered.
- When a group of bike racks are provided, at least 36 inches should be provided between bike racks. 48 inches- 60 inches of space should be allotted between parallel racks. A minimum clear distance of 36" should be provided between a bicycle rack and other streetscape elements so that the bike rack is functional. Although bike racks can be installed with a minimum 24 inches offset from curbs, a 36 inches minimum offset is preferable adjacent to on-street parking to maintain usable parking for bicycles and access to motor vehicle doors. See Figure 6-24 for different bike rack orientations.
- Bikeshare docks typically feature semi-permanent structures that hold bicycles, while scooters may be parked in spaces designated by pavement markings and/or signage. Scooter stands may be installed to prevent scooters from tipping over.
- Racks should be placed a minimum of 5 ft. from all fire hydrants.
- Orient racks to facilitate easy access to dockless mobility vehicles.
- Where bicycle parking is placed alongside on-street parking, bike racks should be placed to avoid conflicts with the parked vehicle's opening doors.
- Bikeshare pay and informational kiosks (if provided) should be accessed from the sidewalk.
- Co-locate multiple dockless mobility options in the same location to maximize transportation choices and efficiency and minimize clutter. Additionally, consider co-locating hubs with rideshare pick-up/drop-off locations to create multimodal mobility hubs.
- Bicycle parking and bikeshare stations may be installed within the pavement of a roadway in place of on-street parking to provide direct access to and from bikeways and eliminate conflicts with pedestrians on the sidewalk. When used, flexible delineators or other vertical elements should be used to prevent motorist encroachment into the bicycle parking area. See Figure 6-25 for an example of a bikeshare station installed in place of on-street parking. When feasible, additional space between the bike parking area and the adjacent travel lane (e.g., bike lane or vehicle lane) will provide additional maneuverability but given a constrained scenario this may not always be possible.
- Bike parking and bikeshare dock installations should comply with the clear zone guidance specified in L&D Manual Volume 1, Section 600.2.

Figure 6-24: Typical Bike Parking Spacing for Parallel, Diagonal, and Longitudinally Oriented Inverted U Racks

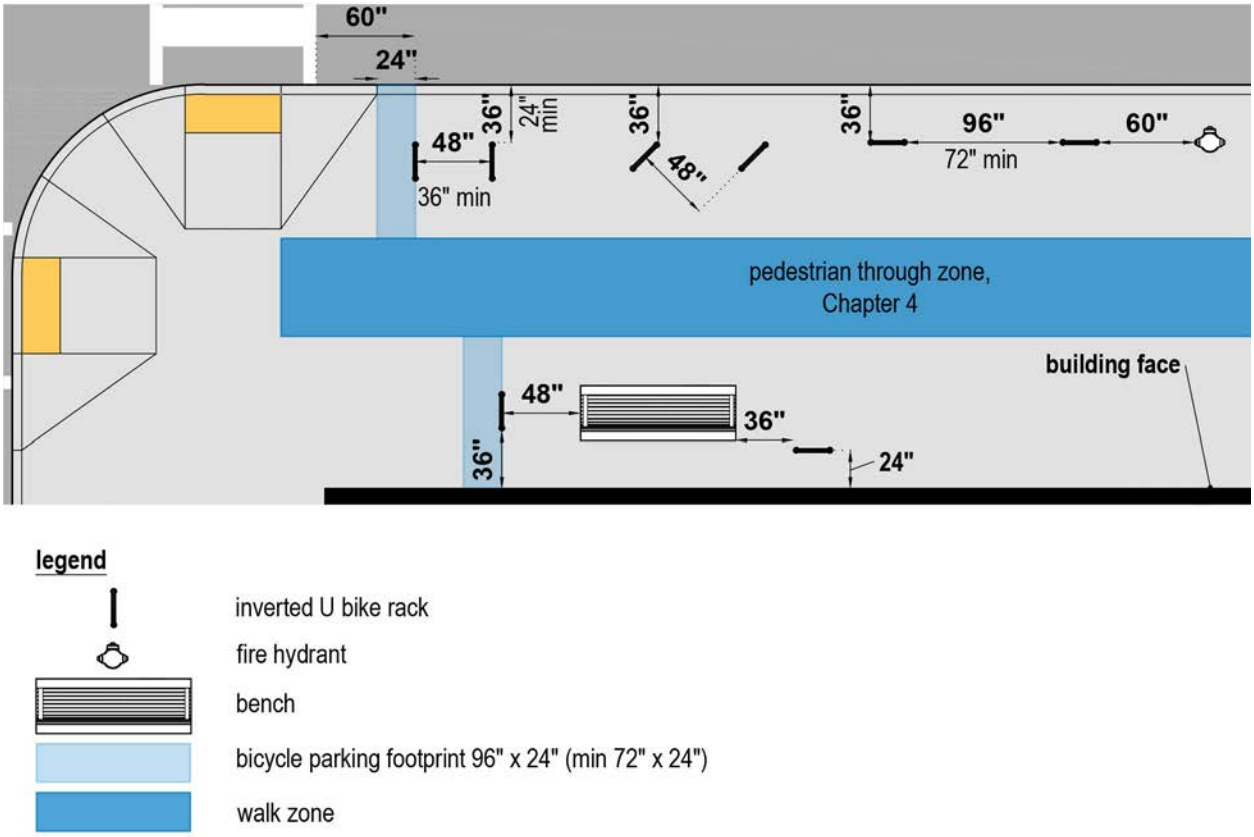
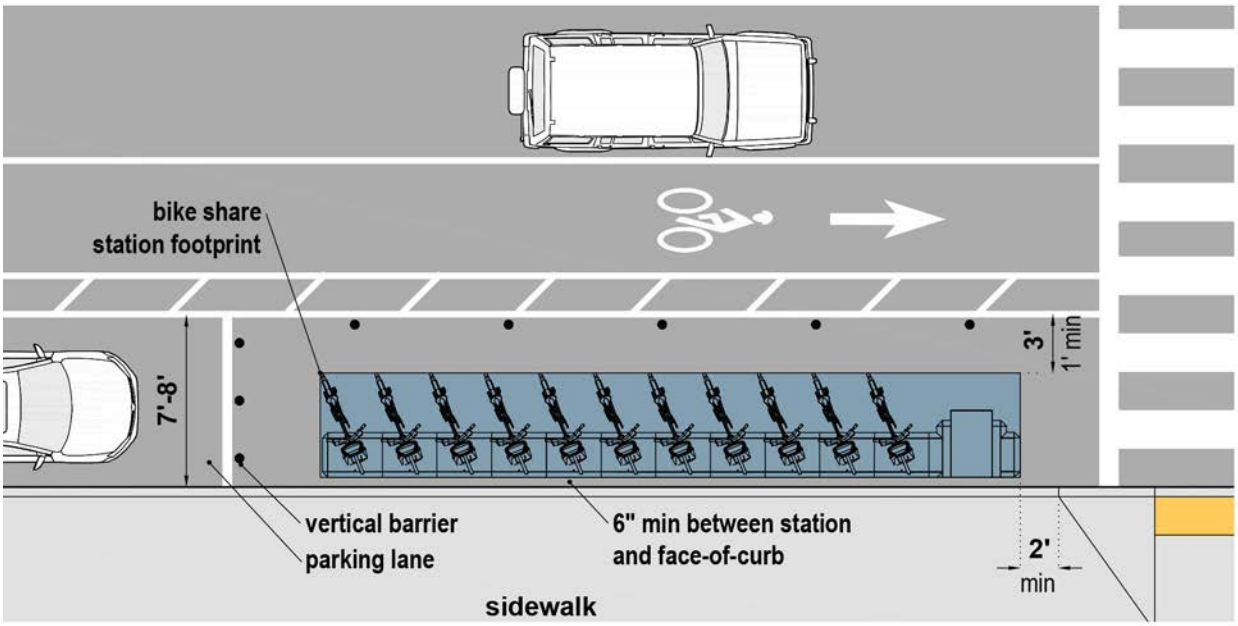


Figure 6-25: Example of Bikeshare Stations Installed Within a Roadway



6.4 Evaluations of Uncontrolled Roadway Approaches to Bicycle Crossings

Where it is determined that bicycle approaches to intersections must be yield- or stop-controlled, the designer should evaluate traffic characteristics and quantify crossing opportunities where motor vehicles have an uncontrolled approach to the bicycle crossing. At these locations, natural crossing opportunities are created when motorists yield to crossing pedestrians, or when there are sufficient crossing opportunities (e.g., gaps) in traffic for bicyclists to cross. Table 6-8 identifies the recommended number of bicyclist crossing opportunities per hour that should be available at uncontrolled crossings. If sufficient crossing opportunities are not available, bicyclists are likely to accept smaller gaps or avoid the bikeway entirely due to the uncomfortable or inconvenient crossing conditions.

Table 6-8: Recommended Hourly Crossing Opportunities

Major Street Crossings (opportunities per hour)	
Preferred	120
Minimum	60

A gap study may be used to evaluate the availability and frequency of safe crossing gaps, defined as critical gaps in the *Highway Capacity Manual* (HCM). The HCM provides a methodology to calculate the average pedestrian delay for an uncontrolled crossing. This approach may also be used to evaluate bicyclist delay at an uncontrolled crossing. The critical gap is determined by calculating the pedestrian or bicyclist departure sight distance that allows a person enough time to judge a gap and complete a full crossing of the roadway (see Section 3.5.2. Intersection Sight Distance – Case D).

Designers should evaluate the crossing opportunities provided during the peak hour, as well as the peak 15-minute period, similar to the evaluation of level of service for motorized traffic. Where sufficient crossing opportunities are not provided, countermeasures should be provided to increase the frequency of opportunities (see Section 6.4.1).

6.4.1. Countermeasures to Improve Yielding

At locations where gaps do not provide the recommended minimum crossing opportunities (Table 6-8), engineering countermeasures to increase crossing opportunities should be considered. For roadways operating over 30 mph, it may be necessary for a traffic control device to display a red signal to require motorists to stop for bicyclists (and pedestrians) crossing roadways at locations where gaps in traffic are not sufficient (See Tier 3 in Table 6-9).

In many contexts, the installation of multiple countermeasures may improve yielding and safety outcomes. Tier 1 should be considered as the base countermeasures that support Tier 2 and 3 countermeasures. Tier 1 and 2 countermeasures should support Tier 3 countermeasures.

Tier 1 Countermeasures

- The goal of Tier 1 countermeasures is to clearly communicate the presence of a crossing to all users as the traffic volumes and speeds are conducive to motorists yielding. Where bike lanes are present, provide Bicycle Crossing Markings and Signs (see Section 6.5.1 and Section 6.7)

Table 6-9: Uncontrolled Crossing Evaluation Table[8,9,10]

Uncontrolled Crossing Countermeasure Evaluation Table												
Roadway Type	**Vehicle ADT < 9,000**			**Vehicle ADT 9,000 - 12,000**			**Vehicle ADT 12,000 - 15,000**			**Vehicle ADT > 15,000**		
(Number of Travel Lanes and Median Type)	**Speed Limit (mph)**											
	≤30	**35**	**40≥***	**≤30**	**35**	**40≥***	**≤30**	**35**	**40≥**	**≤30**	**35**	**40≥**
2 Lanes	1	1	2	1	1	2	1	1	3	1	2	3
3 Lanes with raised median	1	1	2	1	1	2	1	2	3	2	2	3
3 Lanes without raised median	1	1	2	1	2	2	2	3	3	2	3	3
4 Lanes with raised median**	1	1	2	1	2	2	2	3	3	3	3	3
4+ Lanes without raised median	1	2	3	2	2	2	3	3	3	3	3	3

* Where the speed limit exceeds 40 mph, Tier 3 should be considered

** Raised medians must be at least 6 feet wide to serve pedestrians. See Figure 3-2 for different bicycle lengths to serve bicyclists. Where median width is less than these values, review category of 4+ lanes without raised median.

legend

Tier 1: 1

Tier 2: 2

Tier 3: 3

- Improve Intersection Sight Distance:
  - » Where intersection sight distance for either party is limited, consider removing parking or other sight obstructions, or installing curb extensions (see Chapter 4) to allow bicyclist to wait closer to the edge of the traveled way to shorten the crossing distance.
  - » Where minimum intersection sight distances cannot be provided, stopping sight distance must be provided and advance warning beacons and signage should be installed (see Chapter 8).
  - » Additional options for scenarios where neither intersection or stopping sight distance can be achieved include relocating the crossing or evaluating it for a signal or other traffic control device (i.e., stop sign, rectangular rapid flashing beacon, pedestrian hybrid beacon, etc.).

- Reduce Approach Speeds:
  - » Designers can complete a speed study and may be able to lower the posted speed limit. A reduction in the posted speed limit should be complemented by street design changes to reinforce the desired operating speed. Section 7.8 covers speed management and traffic calming measures.

Tier 2 Countermeasures

In addition to Tier 1 countermeasures, designers should consider the following as speeds, volumes, and roadway widths increase to clearly communicate the presence of the crossing to all roadway users.

- Optimize Geometric Design:
  - » The geometry of the intersection and crossing should be optimized to be as close to 90 degrees as practical to minimize the exposure of crossing users, reduce crossing distances, and maximize sight lines.
  - » The crossings should be shortened to reduce exposure and increase the frequency of safe crossing gaps. Strategies to consider include travel lanes, travel lane removal, crossing islands, and curb extensions (see Chapter 7).
- Reduce approach speeds (see Tier 1 Countermeasures).
- Provide active beacon or rectangular rapid flashing beacon (see Chapter 8).

Tier 3 Countermeasures

The goal of Tier 3 countermeasures is to require motorists to stop for crossing bicyclists (and pedestrians) at a pedestrian hybrid beacon or traffic signal or to eliminate the conflict using grade separation (see Section 6.6). These roadways where Tier 3 countermeasures are appropriate have higher volumes and speeds where crossing opportunities are less likely. Tier 3 recommendations require an evaluation of OMUTCD warrants for signalized treatments, see Section 8.2. Where these options are considered, bicyclists must either be ramped from the street to a side path to access pedestrian pushbuttons or pushbuttons or other detection methods must be provided within the street. See Chapter 8 for guidance on beacons and signalization for bicyclists.

6.5 Intersections and Bicycle Crossings

This section discusses the design of bikeways at intersections and crossings. The preferred design treatment at every intersection and crossing should be selected based on the following design principles:

- Minimize exposure to conflicts
- Reduce speeds at conflict points
- Provide adequate sight distance
- Communicate right of way priority

- Provide clear transition between bikeway types
- Accommodate people with disabilities

6.5.1. General Bikeway Design at Intersections & Crossings

Separation of Modes

It is preferred that a bikeway and any physical separation provided along a bikeway be maintained up to intersections. Sections 6.5.2, 6.5.3, and 6.5.6 discuss when additional physical separation may be appropriate based on speeds, volumes, and contexts. In some instances, it may not be feasible to maintain a bikeway and separation to an intersection, which will necessitate specific design considerations and may not maintain the desired level of comfort and safety for the selected bikeway. Chapter 8 provides guidance for separating users through signalization strategies and Chapter 9 provides additional design treatments at complex intersections and roundabouts.

Visibility of All Users

Adequate sight lines are needed between all roadway users as they approach an intersection. Section 3.5 defines sight distance requirements for different intersection scenarios. Due to the mixed nature of traffic at intersections (pedestrians, bicyclists, and motorists), the designer should keep in mind the speed of each travel mode and its resulting effect on design values when considering design treatments. The fastest vehicle should be considered for approach speeds (typically the motor vehicle and bicycle) because these modes require the greatest stopping distance. By contrast, for departures from a stopped condition, the characteristics of slower users (typically pedestrians and bicyclists) should be considered due to their greater exposure to cross traffic.

When a separated bike lane or side path is located behind a parking lane, it is typically necessary to restrict parking and other vertical obstructions near a crossing to ensure adequate sight distances are provided. At intersections and driveways with permissive turning movements where bicyclists and motorists are traveling in the same direction, parking restrictions (and the resulting sight distances) are a key consideration. See Section 3.5. At intersections and driveways with stop signs, where motorists must stop before turning across the separated bike lane or side path, the standard parking restricted area adjacent to the intersection (20 ft. minimum from a crosswalk and 30 ft. prior to a traffic control device at per ORC 4511.68 (6), (7)) may be adequate. More discussion of driveways is provided in Section 6.5.8.

Speed Minimization

If conflict points cannot be eliminated, intersection designs should minimize the speed differential between users at the points where travel movements intersect. Reducing speeds, particularly of motor vehicles, at conflict points may allow all users more time to react to avoid a crash and can reduce the severity of a potential injury if a crash does occur. Intersections where bicyclists operate should be designed to prioritize slower-speed turning movements and weaving movements across the path of bicyclists. Treatments for reducing speed and improving safety at conflict points are

provided in subsequent sections based on the bikeway type and roadway configuration and Chapter 7 provides design guidance for the various traffic calming treatments as well as a discussion of design and check vehicles for evaluating corner radii.

Communicate Right of Way Priority

Intersection design should provide bicyclists, pedestrians, and motorists with cues that both clearly establish which user(s) have the right of way and consistently communicate expected yielding behavior. Traffic control devices should communicate right of way priority through the provision of:

- Marked pedestrian crossings of bikeways;
- Marked bicycle crossings (lane extensions) at driveways and intersections;
- Regulatory or warning signs for motorists and/or bicyclists who are crossing, merging, or turning where appropriate;
- Signalization where provided.

Regulatory and warning signs will depend on the bikeway type and lane configuration and is discussed for each treatment type. At signalized intersections, bicyclists may be controlled by motor vehicle signals, pedestrian signals, or bicycle signals. A bicycle signal provides a separate indication for the exclusive use of bicyclists. See Chapter 8 for bicycle signalization design considerations.

Intersection Pavement Markings

Intersection pavement markings are used to highlight conflict areas and aid bicyclist navigation. Table 6-10 summarizes the preferred pavement markings based on the intersection and bikeway type.

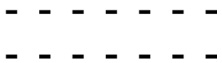
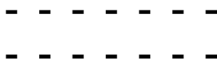
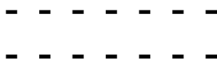
Bicycle Crossing Markings (Lane Extension Lines)

Where a bikeway crosses an intersection separate from a crosswalk, bikeway lane markings may be extended through the intersection to delineate the bicycle crossing and raise awareness of the presence of bicyclists. Bike lane crossings are desirable to:

- Delineate a preferred path for people bicycling through the intersection, especially crossings of wide or complex intersections,
- Improve the legibility of the bike crossing to roadway users, and
- Encourage motorist yielding behavior, where motorists must merge or turn across the path of a bicyclist.

Figure 6-26 provides design details for bicycle crossing markings. Bicycle crossings should consist of dotted extensions lines, which should at least match the width of the line it is extending. 6 inches is a typical width for a bicycle dotted extension line, but wider extension lines should be considered to further emphasize the crossing and improve the longevity of the markings. Bicycle lane symbols may be added within lane extension lines to communicate the directionality of the bike lane, which may be beneficial in areas where two-way separated bike lanes or counter flow bike lanes are present.

Table 6-10: Bicycle Crossing and Intersection Markings Selection Guidelines

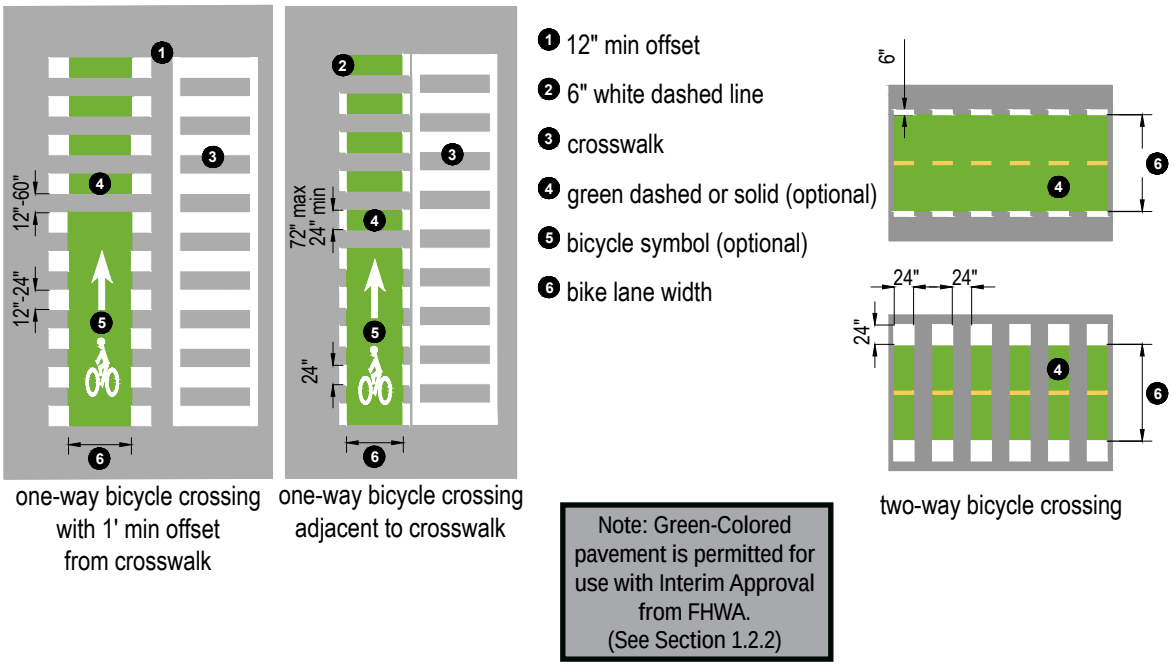
Intersection Type	Condition	Separated Bicycle Lane	Conventional/ Buffered Bike Lane	Bicycle Boluevard
Signalized	Turn Conflict			No Markings
	No Turn Conflict			No Markings
	Bikeway Corridor Turns Left			
Unsignalized	High Turning Volume			No Markings*
	All other conditions			No Markings
	Bikeway Corridor Turns Left			No Markings

*Additional treatment may be needed

Bicycle crossings may also be supplemented with green-colored pavement. If used, the green-colored pavement should align with the dotted extension line pattern of the dotted edge lines. If the green-colored bike crossings are proposed parallel to pedestrian crosswalks comprised of wide longitudinal lines (i.e., high visibility crosswalks) the dotted extension lines and green-colored pavement should align with the crosswalk markings. See Figure 6-26. This placement will reduce pavement marking clutter and ensure that the green-colored markings are spaced to avoid motorist wheel paths and improve the longevity of the markings.

At locations where the bicycle crossing is less than 1 ft. from the pedestrian crossing, the dotted extension line nearest the pedestrian crossing can be removed, allowing the edge of the crosswalk to serve as the edge of the bicycle crossing.

Figure 6-26: Bicycle Crossing Pavement Markings



Two-Stage Bike Turn Box (Interim Approval)

Figure 6-27 designates an area at an intersection intended to provide bicyclists a place to wait for traffic to clear before proceeding in a different direction of travel. To use the two-stage bike turn box, bicyclists traverse the intersection within the bike lane, stop within the turn box, reorient themselves to the cross street, and wait for the signal for the cross street to proceed, eliminating the need to merge across travel lanes.

Two-stage bicycle turn boxes may be used for left or right turns, and its use is preferred for making turns instead of a bike box (see Section below), particularly on higher-volume or multi-lane roads. A two-stage bike turn box may be used at signalized intersections per FHWA Interim Approval IA-20.12. The use of a two-stage turn box at an unsignalized intersection is not an approved use of this treatment and would require an experimental approval from FHWA.

Two-stage turn boxes should be installed where a bikeway intersects with another designated bikeway or where it would connect to a major destination, such as a school, community center, grocery store, etc. When designing a buffered or separated bike lane, designers should plan on installing two-stage turn boxes at most intersections to discourage merging with traffic to make a left turn before reaching intersections. When designing a conventional bike lane, if the volume or speed of the adjacent roadway is more than 6,000 ADT or 30 mph, designers should consider installing two-stage turn boxes at intersections.

Figure 6-27: Two-Stage Bike Turn Box Pavement Markings

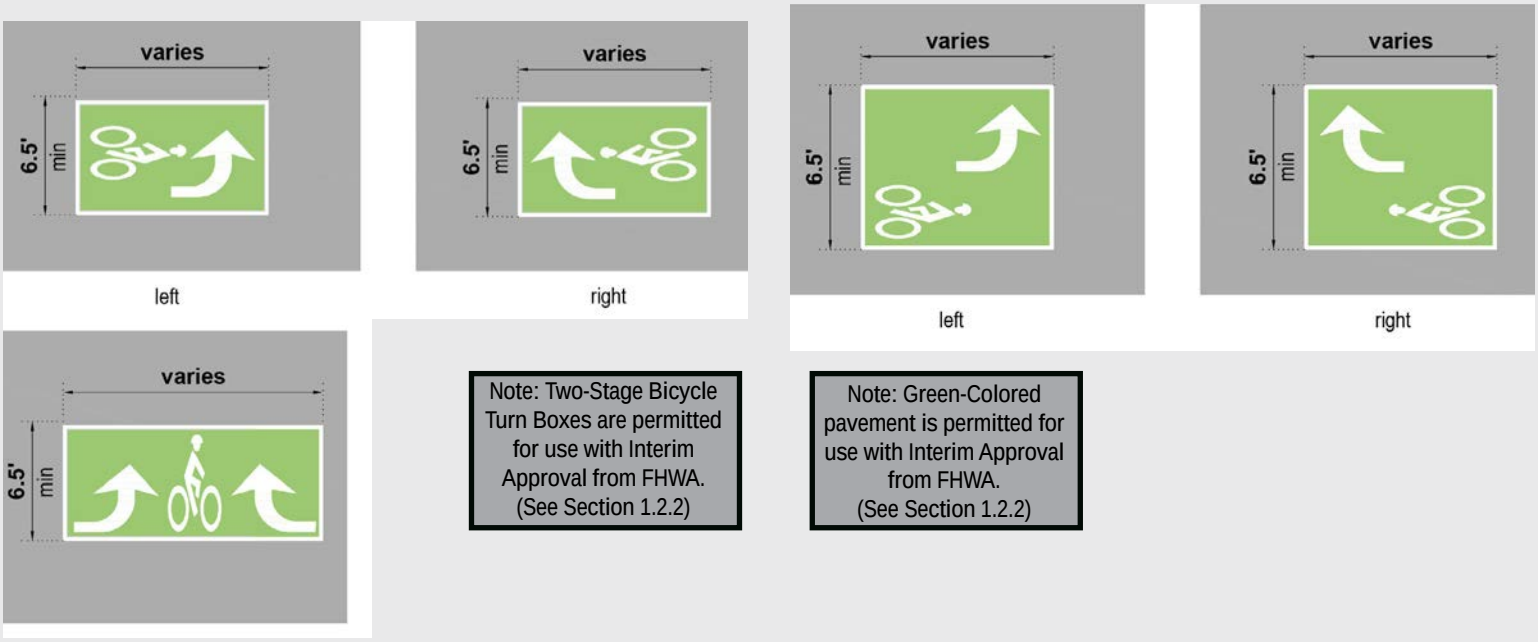
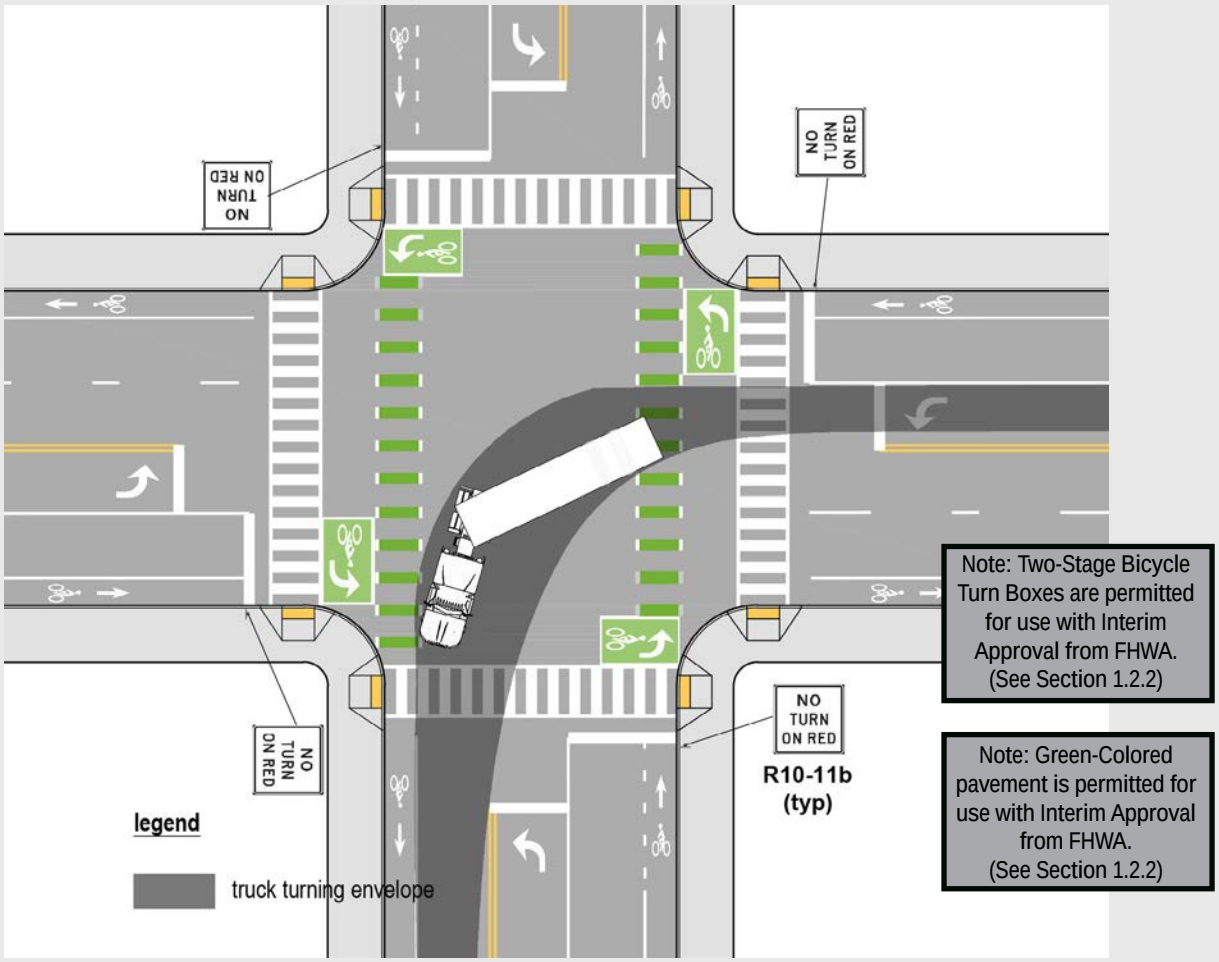


Figure 6-28: Two-Stage Left Turn Box Placement


NO TURN ON RED
NO TURN ON RED
NO TURN ON RED
NO TURN ON RED
R10-11b (typ)
legend
truck turning envelope
Note: Two-Stage Bicycle Turn Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

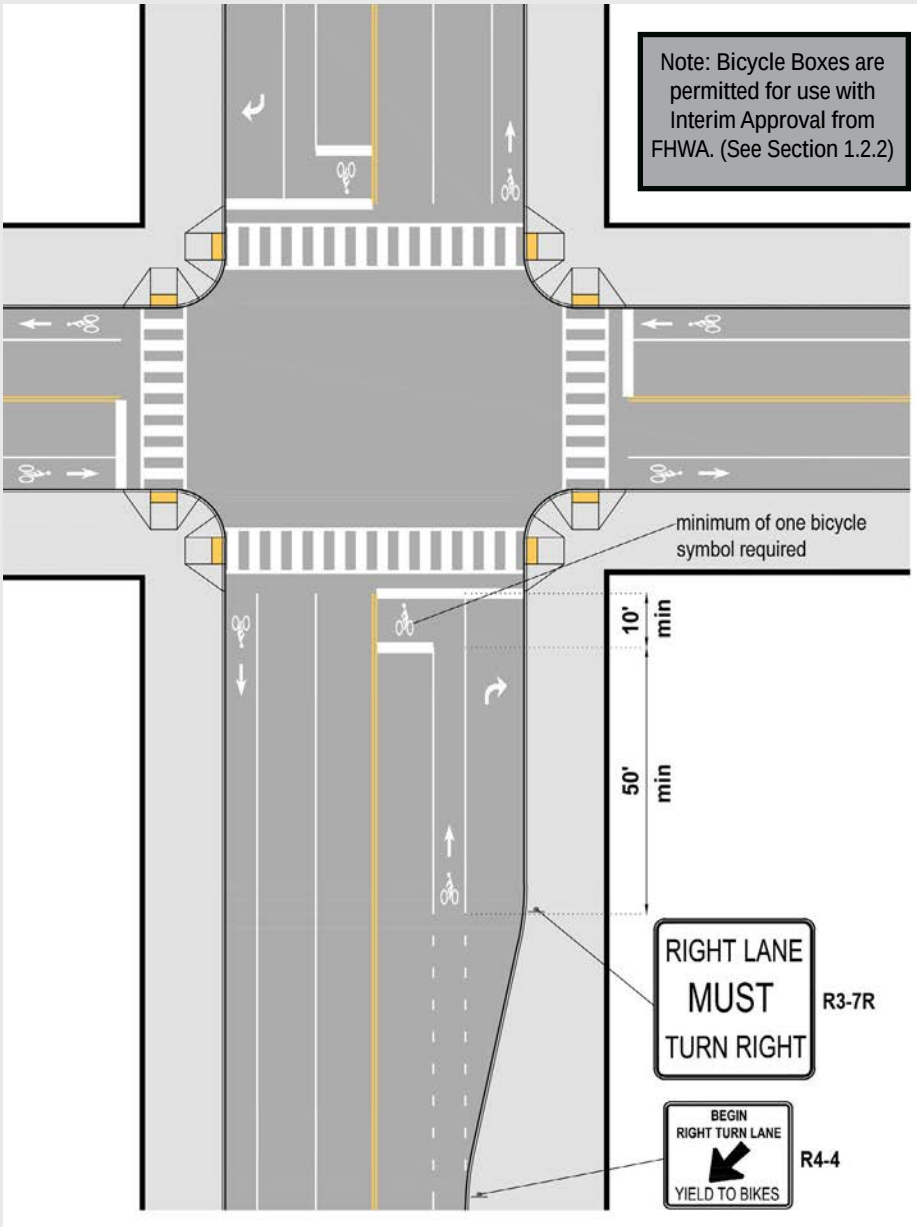
A two-stage bike turn box:

- Must be located outside of the path of through and turning traffic;
- Should be located adjacent to the direct path of bicyclist travel;
- Should be located downstream of the crosswalk and downstream of the stop line;
- Should be located in an area clearly visible to motorists and adequately illuminated;
- Must include a bicycle symbol, preferably oriented in the direction in which the bicyclists enter the box, along with an arrow showing the direction of the turn; and
- May include green-colored pavement or pavement markings to enhance the conspicuity of the box.

A NO TURN ON RED (R10-11) sign must be installed where a two-stage bike turn box is not located outside the path of right-turning traffic to prevent motorists from entering the bicycle queuing area. The placement must also consider left-turning traffic that may otherwise overlap with the two-stage bike turn box. Passive detection of bicycles in the two-stage bike turn box must be provided if detection is required to actuate a traffic signal.

Two-stage bicycle turn box dimensions vary based on the street operating conditions, the presence or absence of a parking lane, traffic volumes and speeds, and available street space. The queuing area should be a minimum of 6.5 ft. deep measured in the longitudinal direction of bicycles sitting in the box. The box must be outlined with solid white lines.

Figure 6-29: Bicycle Box Configuration Across One Lane of Through Traffic


Note: Bicycle Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)
minimum of one bicycle symbol required
10' min
50' min
RIGHT LANE MUST TURN RIGHT
R3-7R
BEGIN RIGHT TURN LANE
YIELD TO BIKES
R4-4

Bike Boxes (Interim Approval)

A bicycle box is a designated area on the approach to a signalized intersection consisting of an advanced stop line and bicycle symbol. Bike boxes mitigate conflicts between through bicyclists and right-turning motorists, reduce conflicts between motorists and bicyclists at the beginning of the green signal phase, and provide additional queuing space for bicyclists. Bike boxes should not be installed across more than one through travel lane with the intention of accommodating bicyclist turns; however, FHWA Interim Approval IA-18.10 does permit this installation with certain conditions. A two-stage bicycle turn box should instead be used to accommodate bicyclist turns. The use of bike boxes is limited to signalized intersections and should not be used in other locations.

At least one bicycle symbol should be placed in the box to indicate it is for bicycle use. Bike boxes should be a minimum of 10 ft. in depth and may be larger depending on anticipated bicyclist volumes. At least 50 ft. of bike lane should be provided on the approach to a bike box so bicyclists will not need to ride between lanes to enter the box. The approaching bike lane, and the bike box, may be colored green.

The stop line for motorists should be set back to coincide with the beginning of the bike box. The sign STOP HERE ON RED (R10-6 or R10-6A), aligned with the motorist stop line, should be installed to indicate the correct stopping location for motorists, with an EXCEPT BICYCLES (R3-7bP) word legend plaque. The sign STOP HERE ON RED (R10-6 or R10-6A) should not be used in locations with a separate turn lane where motorists are stopping in two different locations (see Figure 6-29).

Turns on red should be prohibited on the approach where a bike box is placed in front of traffic that has potential to turn on red, using a NO TURN ON RED sign (R10-11 series). At intersections where a high number of collisions occur between through bicyclists and turning vehicles, alternative treatments should be considered such as a protected intersection (see Section 6.5.2), leading or exclusive bicycle signal phases (see Chapter 8), separate lanes for through and turning traffic, or a combination of these and other treatments.

6.5.2. Separated Bike Lanes at Intersection Design

A protected intersection (discussed below) is the preferred intersection treatment for separated bike lanes and side paths. When intersections are constrained, designers should consider the following in the order listed:

1. Reduce each roadway element (motor vehicle lanes, buffers, separated bike lanes, and sidewalk) to its minimum dimensions or minimum number of travel lanes necessary.
2. Eliminate the sidewalk buffer while still providing a detectable edge adjacent to the road for pedestrians with disabilities (see Chapter 4).

3. Provide a conventional bike lane or mixing zone (not appropriate for side paths or two-way separated bike lanes) by transitioning the separated bike lane to:
    - » A conventional bike lane with an optional bicycle ramp to the sidewalk for roadways with operating speeds of 35mph or greater. If local jurisdictions prohibit bicycle use on sidewalks, this option is limited to when the ramp leads to a side path or shared use path or requires a sign to indicate that a bicyclist must dismount and walk their bike.
    - » A conventional bike lane or shared lane for roadways with operating speeds of less than 35 mph.
4. These options are further discussed below and in Section 6.5.3 for conventional bike lane designs.

General Intersection Design

The principles and basic pavement marking treatments of intersection design are covered in Section 6.5.1. This section covers only issues that are unique to separated bike lane and side path intersection designs.

Reducing Speed at Conflict Points

Where motorists are permitted to turn across the path of bicyclists, intersections should be designed to reduce motorist turning speeds. Designers should apply the following treatments for reducing motorist turning speeds when feasible based on the roadway context:

- At protected intersections, the effective radius of the intersection corner plays a significant role in determining the speed at which turning motorists may negotiate the corner. See the Protected Intersection section below and Chapter 7 for design information regarding reducing turning speed through the use of corner islands, truck apron treatments, and design and check vehicles.
- The speed of left-turning motorists crossing a bikeway should also be considered. Channelizing devices such as median islands and hardened centerlines (see Chapter 7) can be used to establish a smaller turning radius, reducing the speed of motorists, which can improve yielding and reduce the severity of crashes.
- Raised crossings can also be an effective treatment for reducing both left and right turning vehicle speeds, increase visibility of bicyclists, and increase yielding behavior of motorists. See Chapter 7 and the bike ramp discussion in Section 6.3.8.

It may also be necessary to slow the speed of bicyclists approaching an intersection, especially where the grade of the roadway will frequently result in a higher speed of travel.

- Bending the bike lane away from the adjacent motor vehicle lane is preferred, as this creates a larger offset at the intersection from turning vehicles, while also introducing horizontal deflection in the bike lane. The offset may also allow for the provision of a corner island or protected intersection. The horizontal deflection should follow the bicycle taper rate design criteria specified in Chapter 3 using the desired operating speed.
- Where horizontal deflection is not feasible due to geometric constraints, designers may consider vertical deflection for bicyclists, raising the elevation of the bikeway to reduce their speed as they

approach an intersection. See the following Transitions between Elevations section for vertical deflection design parameters.

Transitioning Bikeways between Elevations

Separated bike lanes may transition from one elevation to another in order to accommodate:

- Raised crossings at intersections,
- A vertical deflection to slow bicyclists as they approach an intersection, and
- At loading/unloading areas that prioritize pedestrians such as accessible parking, valet parking, transit stops, or ridesharing pick-up/drop-off

The ramp for the bicyclist should provide a smooth vertical transition with a maximum slope of 8 percent; however, a 5 percent slope is generally preferred. For side paths, any transitions must be consistent with pedestrian accessibility guidelines. Speed hump markings should be used on bicycle ramps to allow the ramp to be more visible to bicyclists.

Transition ramps should typically not be located within a lateral shift or curve in the bike lane alignment near an intersection. Transition ramps may impact drainage flow and require additional storm sewer infrastructure.

Restricting Motor Vehicles

Separated bike lane and side paths should be marked with bicycle crossings (Figure 6-26) and crosswalks (Section 4.5.1), respectively, at intersections and driveways. These marked crossing treatments are often sufficient to communicate that motor vehicles are not the intended user of the bikeway. Bicycle lane symbol markings (Section 6.3.4) located close to an intersection or driveway can further reinforce the intended user. Green-colored pavement or markings in the bicycle crossing and/or close to an intersection or driveway can further enhance the conspicuity and reinforce that vehicles are not authorized.

KEEP RIGHT or KEEP LEFT signs (R4-7, R4-8), supplemented with an optional EXCEPT BIKES plaque (Section 6.3.4), can be installed in the street buffer to reinforce that motorists should not enter the bikeway.

If the above-mentioned treatments have been implemented and found to be ineffective, changes to the width of the separated bike lane or side path may be considered. Visually narrowing the width of the bikeway using white edge lines should first be considered. For one-way separated bike lanes, the use of flexible delineators or other vertical elements (Section 6.3.7) may be used to narrow the physical width of a one-way separated bike lane to no more than 6 ft. at intersections and driveways, but these treatments should not be placed in the middle of a one-way separated bike lane. For two-way separated bike lanes or side paths, if the above treatments are found to be ineffective, the treatments from Section 5.6.1 may be considered. A two-way separated bike lane may include a flexible delineator post on the centerline at intersections as a temporary measure to acclimate drivers to the lane configuration and then the flexible delineator can be removed once driver education has occurred.

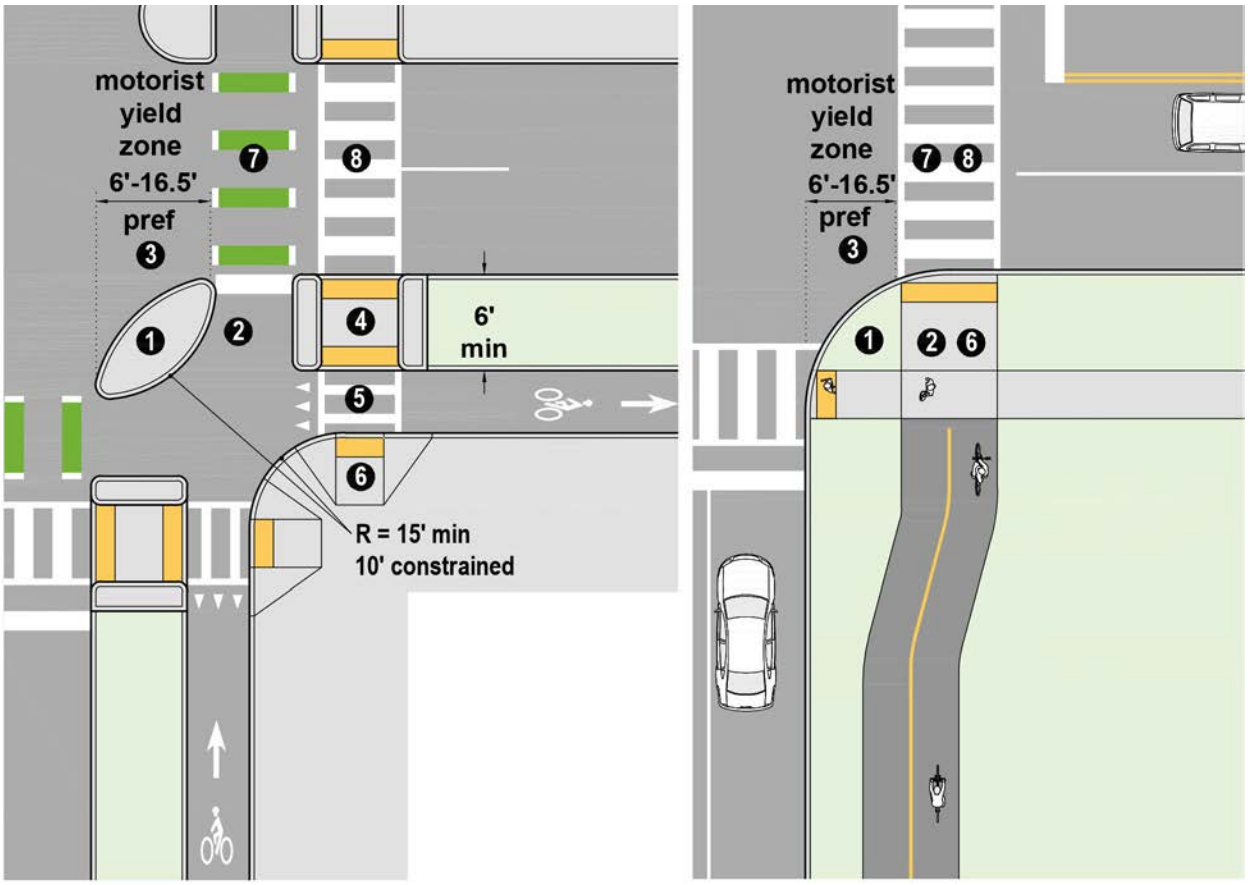
Protected Intersection

Protected intersections maintain bicyclist separation in a separated bike lane or side path up to the intersection using corner islands (vertical elements or curbing) to separate bicyclists from traffic. The design principle may be used at signalized and unsignalized intersections and driveways.

At uncontrolled approaches of intersections and at signalized intersections where turning vehicles and bicycle through movements are expected, designers should offset the bicycle crossing between 6 and 16.5 ft. from the adjacent motor vehicle lane. This treatment creates a yielding space for motorists and has been shown to reduce crashes at uncontrolled and permissive conflict locations. Figure 6-30 shows the design components for a protected intersection.

Designers should consider using a text-only TURNING VEHICLES YIELD TO PEDESTRIANS AND BICYCLES sign to communicate when turning motorists need to yield to these street users.

Figure 6-30: Protected Intersection Design Components



1. corner island
2. forward bicycle queuing area
3. motorist yield zone
4. pedestrian refuge island
5. pedestrian crossing of the separated bike lane
6. pedestrian curb ramp
7. bicycle crossing of travel lanes
8. pedestrian crossing of travel lanes

Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

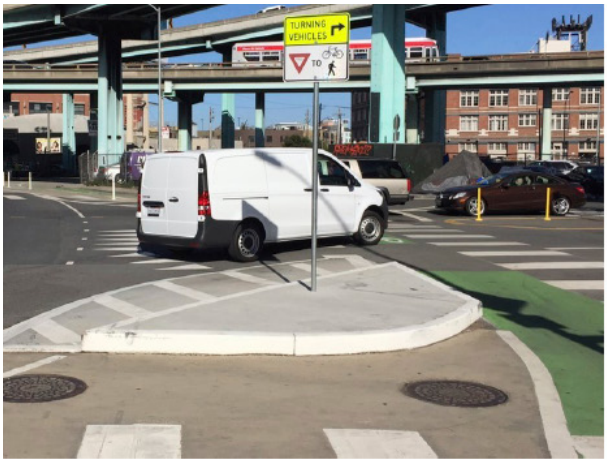
Corner Island

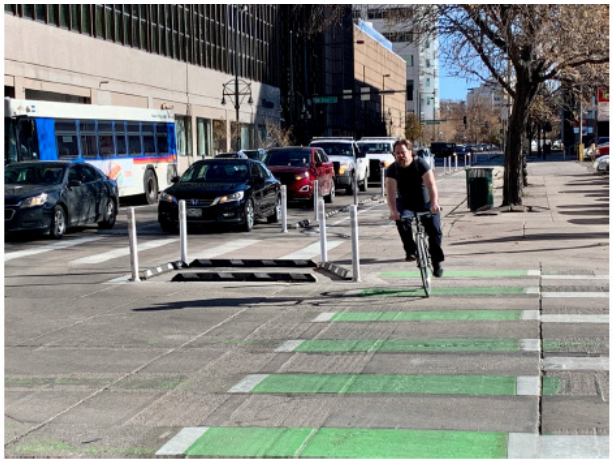
Figure 6-30 shows the corner islands in a protected intersection. The corner island is a key component of a protected intersection, which provides the following benefits:

- Helps establish the horizontal offset between the adjacent motor vehicle lane and the bike crossing, creating a motorist yield zone,
- Provides a defined intersection corner to slow turning vehicles,
- Positions bicyclists waiting to cross ahead of the adjacent motor vehicle lane via an advanced bicycle stop line, allowing bicyclists to be more visible,
- Creates queuing space for bicyclists making a two-stage turn, outside of the path of through bicyclists, thus eliminating the need for some two-stage bicycle turn boxes, and
- Allows for a pedestrian crossing island, shortening the crossing length and reducing exposure.

Corner islands may be constructed of concrete and curbing, or may be constructed with low-cost materials, such as paint and flexible delineator posts or engineered rubber curbs and/or rubber speed cushion (see Figure 6-31). If a corner island is constructed of mountable materials, such as rubber speed cushions, designers should understand that the forward queuing area for bicyclists and pedestrian crossing islands may no longer be protected from turning motorists and should be therefore be removed. Where flex posts or other vertical elements are used, they should be placed at least 1 ft. offset from the turning radius of design vehicles at all intersection and driveways, See Chapter 7 for determining intersection curb radii.

Figure 6-31: Protected Corner Treatment Examples: Concrete Corner Island (left) and Flexible Delineators and Rubber Parking Stops (right)





Pedestrian Considerations

When the street buffer is at least 6 ft. in width, it may be used as a pedestrian crossing island, which can shorten the pedestrian crossing distance. In this case, pedestrians would cross the separated bike lane as an uncontrolled crossing, then cross the motor vehicle lanes as a separate crossing.

When the pedestrian crossing is located at a signalized intersection, the designer can consider reducing the signal timing for the pedestrian crossing to reflect this shorter crossing distance only if the pedestrian pushbuttons are located within the pedestrian crossing island. Yield markings, BIKES YIELD TO PEDS (R9-6) signs, and crosswalk markings should indicate the right of way between bicyclists and pedestrians at these locations.

When the street buffer is less than 6 ft. in width and there is not space for a pedestrian crossing island, the crossing distance cannot be shortened, and any associated signal timing must be calculated for the entire street width.

When on-street parking is located along a corridor, normal parking restrictions at intersections will allow space for a wider street buffer as the separated bike lane approaches the intersection. When there is no parking along the corridor, an offset can be created by narrowing or removing the sidewalk buffer and increasing the width of the street buffer as the separated bike lane approaches the intersection (i.e., bending the bikeway out, away from the adjacent travel lanes).

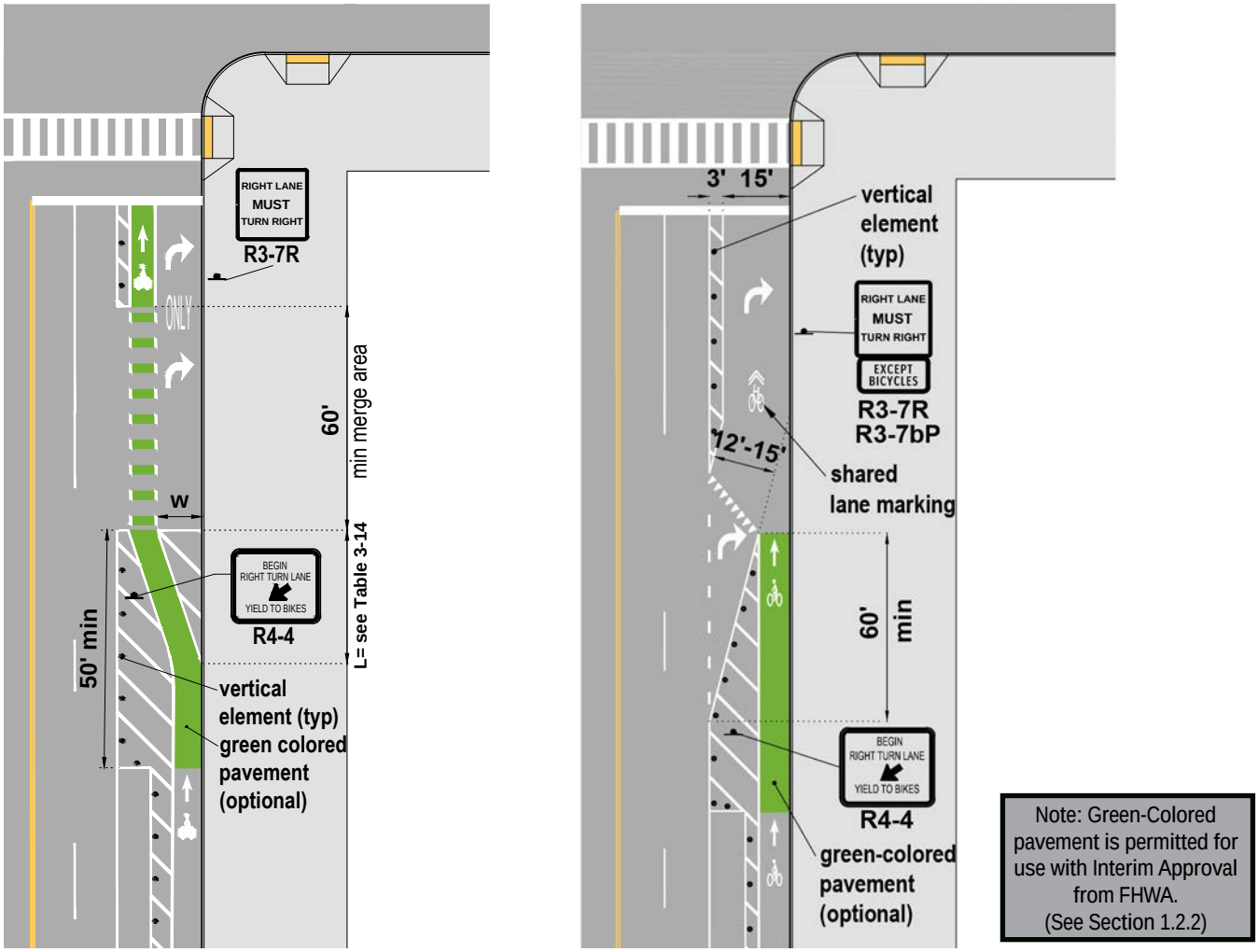
Separated Bike Lanes with Mixing Zones at Intersections

Where protected intersections are not viable, or where separate signal phasing cannot be provided between right-turning motor vehicles and bicycles, the following mixing zone options may be considered for separated bike lanes at intersections. Mixing zones create a defined merge point for a motorist to yield and cross paths with a bicyclist in advance of an intersection. They require removal of the physical separation between the separated bike lane and the motor vehicle travel lane, and are therefore generally appropriate as an interim/retrofit solution or in situations where right-of-way constraints make it infeasible to provide a protected intersection.

The speed of motor vehicles at the merge point is a critical factor for the safety and comfort of bicyclists in mixing zones to accommodate the Interested but Concerned Bicyclist profile. The following strategies can be used to reduce speeds of motor vehicles entering the merge point:

- Minimize the length of the merge area to slow motorists prior to the conflict area.
- Locate the merge point as close as practical to the intersection.
- Minimize the length of the storage portion of the turn lane based on anticipated vehicle queue length (see L&D Manual Volume 1, Section 401.6.3).
- Provide a buffer and physical separation (e.g., flexible delineator posts) from the adjacent through lane after the merge area, if feasible.
- Highlight the conflict area with a green-colored pavement and dotted bike lane markings, as necessary, or shared lane markings. See Figure 6-32.

Figure 6-32: Separated Bike Lane to the Left of a Right-Turn Lane (left) or Transitioning to a Shared Right-Turn Lane (right)



6.5.3. Bicycle Lanes at Intersection Design

As a bicycle lane approaches an intersection, designers should provide a continuous and direct route through the intersection, driveway, or alley that is legible to all users of the roadway. Designers should minimize or eliminate conflict areas between bicyclists and motor vehicles, where possible. To minimize the potential for conflicts, designers should adhere to the following design principles:

- Designers should communicate where motorist are expected to yield to bicyclists.
- Bicycles should not operate between turning lanes and moving lanes with traffic operating over 30 mph on either side of them for distances longer than 200 ft. (see further discussion in the Right Turn Only Lanes section).

- Bicycle crossings of weaving or merging movements by motor vehicles operating over 20 mph should be avoided or minimized to a length of 200 ft. or less.
- It is preferable for motorists merging and crossing movements across bike lanes be confined to a location where motor vehicles are likely to be traveling at speeds less than 20 mph.
- It is preferable for bicycle crossings of intersections to be marked (see Section 6.5.1. General Bikeway Design at Intersections & Crossings)

A conventional or buffered bike lane can be transitioned to a protected bike lane and follow the design of a protected intersection to increase the comfort of the bikeway at the intersection. Designers should consider this design as operating speeds reach 35 mph or higher. See Chapter 3 for bicycle lane taper rates and Section 6.5.2 for protected intersection design. When a protected intersection is not feasible for operating speeds of 35 mph or greater or motor vehicle turning volumes exceed 150 turning vehicles per hour, a bicycle ramp (Section 6.3.8) should be considered to give bicyclists a choice to exit the roadway to a side path or sidewalk prior to the intersection.

Approach Markings

Bike lane lines may be solid or dotted on the approach to and within intersections where motor vehicles are permitted to enter a bike lane to prepare for a turning, crossing, or merging maneuver.

The choice between a solid or dotted lane line should be based on several factors including the speed and volume of turning vehicles, the presence of bus stops and frequency of transit use, and the types of vehicles that may cross or enter the bike lane (see Figure 6-6). A key consideration is the legibility of the bike lane network to both bicyclists and drivers and consistency of application within a community.

At locations with infrequent conflicts, the bike lanes should remain solid to the intersections. Dotted lane lines should be used to delineate conflict areas within the bike lane at locations where:

- intersections are signalized and bicyclists and motorists operate concurrently.
- where right turn lanes are not provided and turning motorist volumes are high.
- buses frequently cross the bike lane at transit stops .

As buffered bike lanes approach intersections, the buffer should not be marked where motorists must cross or enter the bike lane and a bicycle crossing should be considered. Where bike crossings are marked, the bike crossing should be widened to match the width of the full bike lane and buffer. Where a bike crossing is not marked, the buffer should be discontinued by dropping the inside lane line along the bike lane as shown in Figure 6-33 to ensure the motor vehicle travel lane is provided a continuous edge line. As buffered bike lanes approach intersections with shared through/right lanes, the buffer may terminate as shown in Figure 6-34.

Shared Through/Right Motor Vehicle Lanes

When bicycle lanes are present on two-lane roadways, designers should see the Approach Marking guidance above for when to provide a solid or dotted line at the intersection approach.

Figure 6-33: Buffered Bike Lane Treatments at Merge Areas

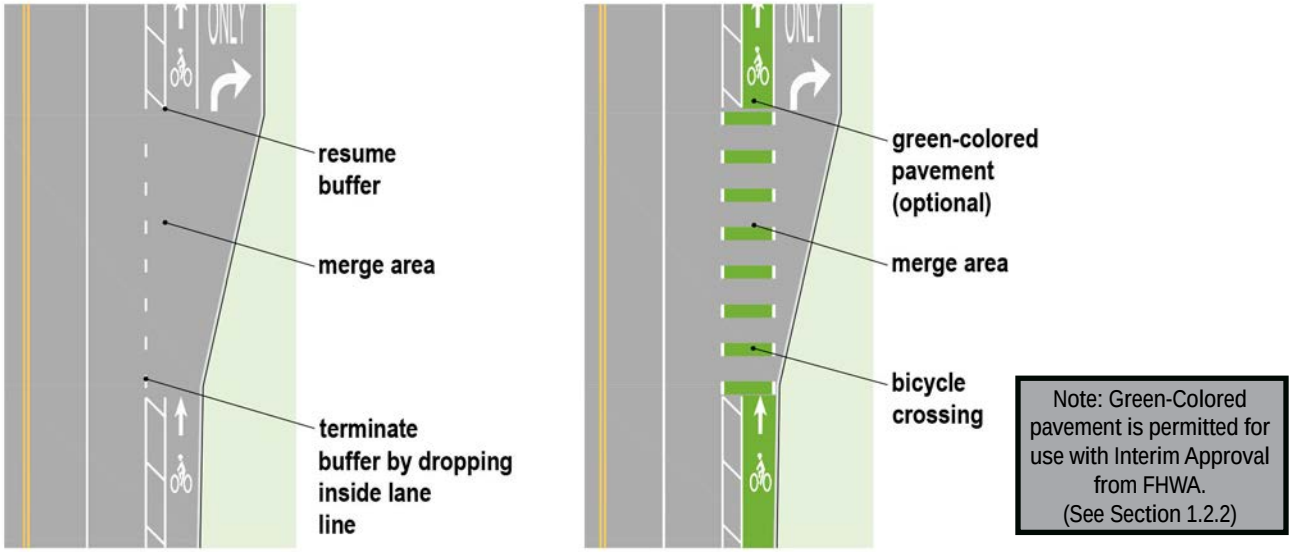
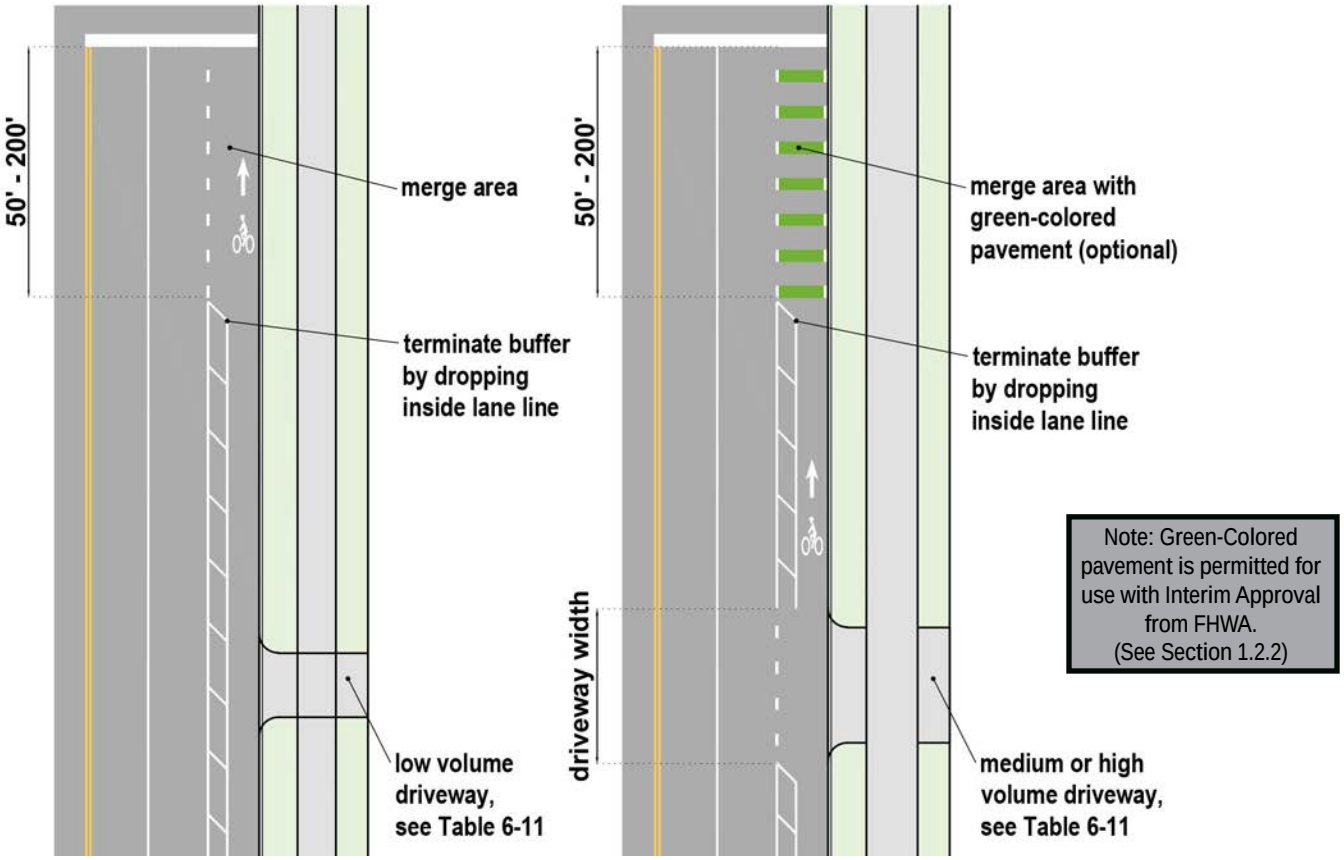
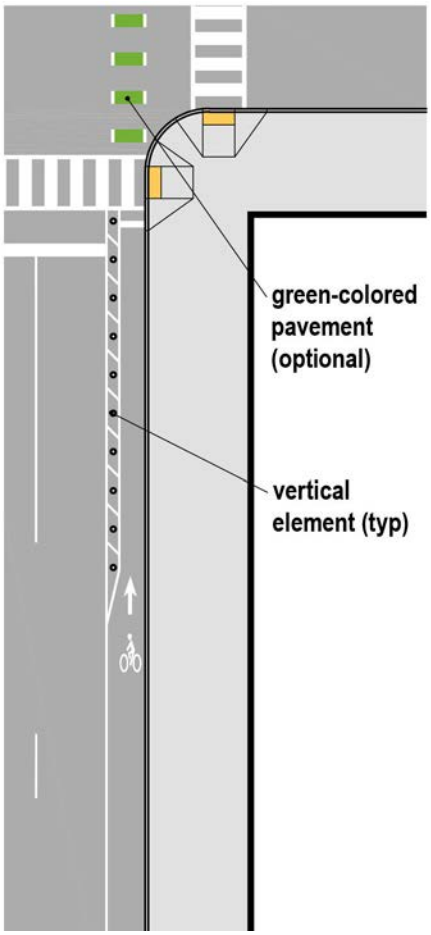


Figure 6-34: Buffered Bike Lane Treatments Approaching Intersections


50' - 200'
merge area
terminate buffer by dropping inside lane line
low volume driveway, see Table 6-11
50' - 200'
merge area with green-colored pavement (optional)
terminate buffer by dropping inside lane line
driveway width
medium or high volume driveway, see Table 6-11
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

At intersection approaches with limited space where a right-turn lane is not required but there are relatively high right-turn volumes (more than 150 vehicles during the peak hour) or an existing crash history, designers should consider converting the conventional bike lane to a separated bike lane by adding a 2 ft. wide minimum buffer with flexible delineator posts beginning at least 50 ft. in advance of the intersection to provide added comfort for bicyclists, slow the speed of turning motorist, and reduce the length of the conflict area (see Figure 6-35). Signal phase separation of bicyclists and motorists should be considered, but if concurrent movements are permitted a bike box or forward bicyclist queuing area should be considered.

Figure 6-35: Bicycle Lane Treatment for high turning volumes from a shared through/right motor vehicle lane

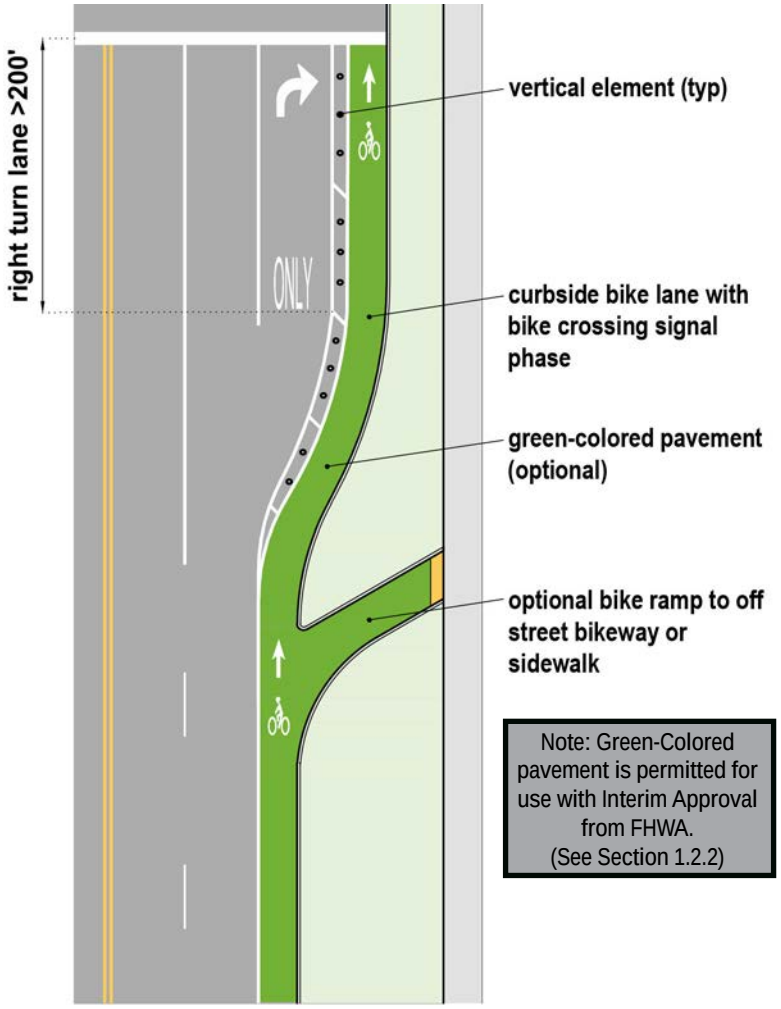


Right Turn Only Lanes

Vehicular right turn only lanes are often used where higher volumes of right-turning motor vehicles warrant an exclusive right turn lane to increase motor vehicle capacity at intersections or for safety benefits. As right turn volumes increase, the potential for conflicts between bicyclists and motor vehicles also increases at merging or crossing locations.

The following are common scenarios for bike lane approaches to intersections with right turn lanes. These scenarios and subsequent treatments are discussed in order of most separated to least separated. Designers should work to provide the highest level of separation feasible to both accommodate the Interested but Concerned user and reduce motorists and bicyclists conflict points.

Figure 6-36: Example Bike Lane Approach to a Right Turn Only Lane


right turn lane >200'
ONLY
vertical element (typ)
curbside bike lane with bike crossing signal phase
green-colored pavement (optional)
optional bike ramp to off street bikeway or sidewalk
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

Right-Turn Only Lane with Separated Bike Lane

At signalized intersections where a right-turn lane is provided, the bike lane can transition to a separated bike lane with the provision of a separate bicycle crossing signal phase. See Figure 6-36.

Bicycle Lane Adjacent to a Right Turn Only

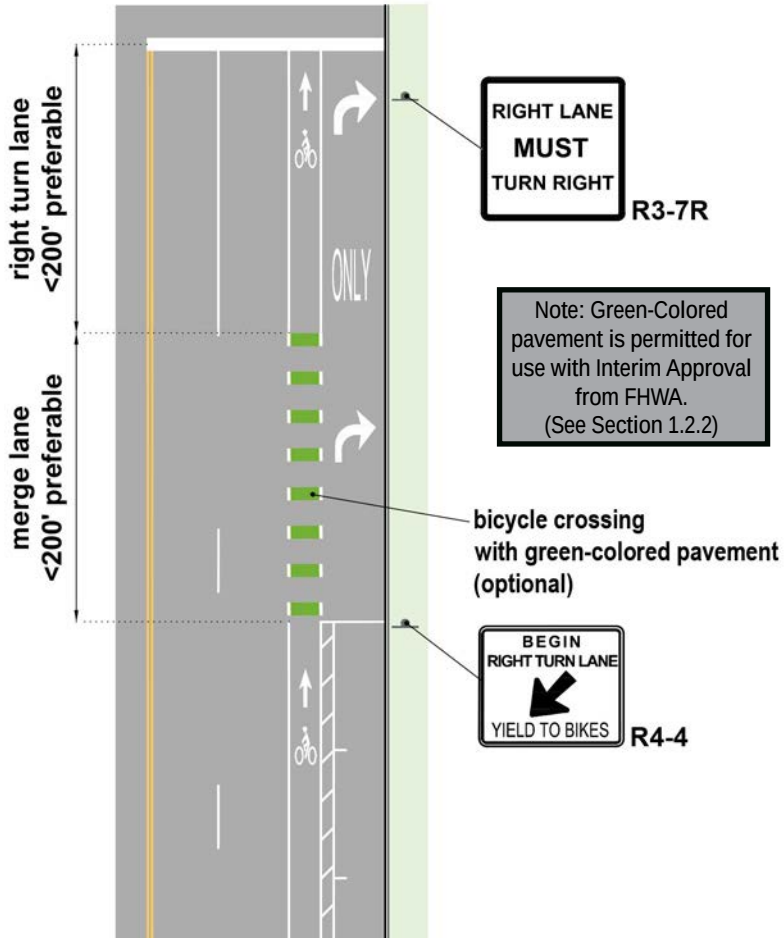
On roadways when a right-turn only lane is added on the approach to an intersection by either widening or by restricting on-street parking, drivers must yield to bicyclists when merging across the bicycle lane into the right-turn lane. To reduce bicyclist exposure on roadways with operating speeds of 35mph or less (see Figure 6-37) and turn lanes less than 200 ft. in length, designers should:

- Mark the merging area with dotted pavement markings for no length greater than 200 ft.
- Mark the merging area where motorists' speeds are lower, typically within 400 ft. of the intersection.

For these locations, designers should:

- Provide the 'BEGIN RIGHT-TURN LANE YIELD TO BIKES' (R4-4) signs to remind drivers of yielding obligations.
- Add green colored pavement to highlight the conflict area and reinforce that drivers should yield to bicyclists.

Figure 6-37: Example Bike Lanes on Streets under 35 mph with Right Turn lanes < 200 Ft. in Length



- Include vertical elements, such as medians or flexible delineators, between the bike lane and through lane to force motorists to enter the turn lane at the clearly defined beginning, thus providing a more predictable conflict point.

On roadways with operating speeds over 35 mph (see Figure 6-38), or at locations where right turn lanes exceed 200 ft. in length, designers should also:

- Provide a bicycle lane as wide as possible, with a bike lane width of 6 ft. or greater and a minimum 2 ft. buffer on either side. In constrained locations, the minimum bike lane width is 4 ft. with a minimum 2 ft. buffer adjacent to the through traffic lane.
- Consider providing a bicycle ramp to allow bicyclists to exit the roadway to an off-street bikeway or sidewalk prior to the merge area, if desired.
- Consider providing mountable medians or flexible delineators within the buffer adjacent to the through travel lane (where present) to prevent motorist encroachment into the bike lane and constrain the motorists merging area across the bike lane.

Figure 6-38: Example Bike Lanes on Streets over 35 mph or Right Turn Lanes > 200 ft. in Length

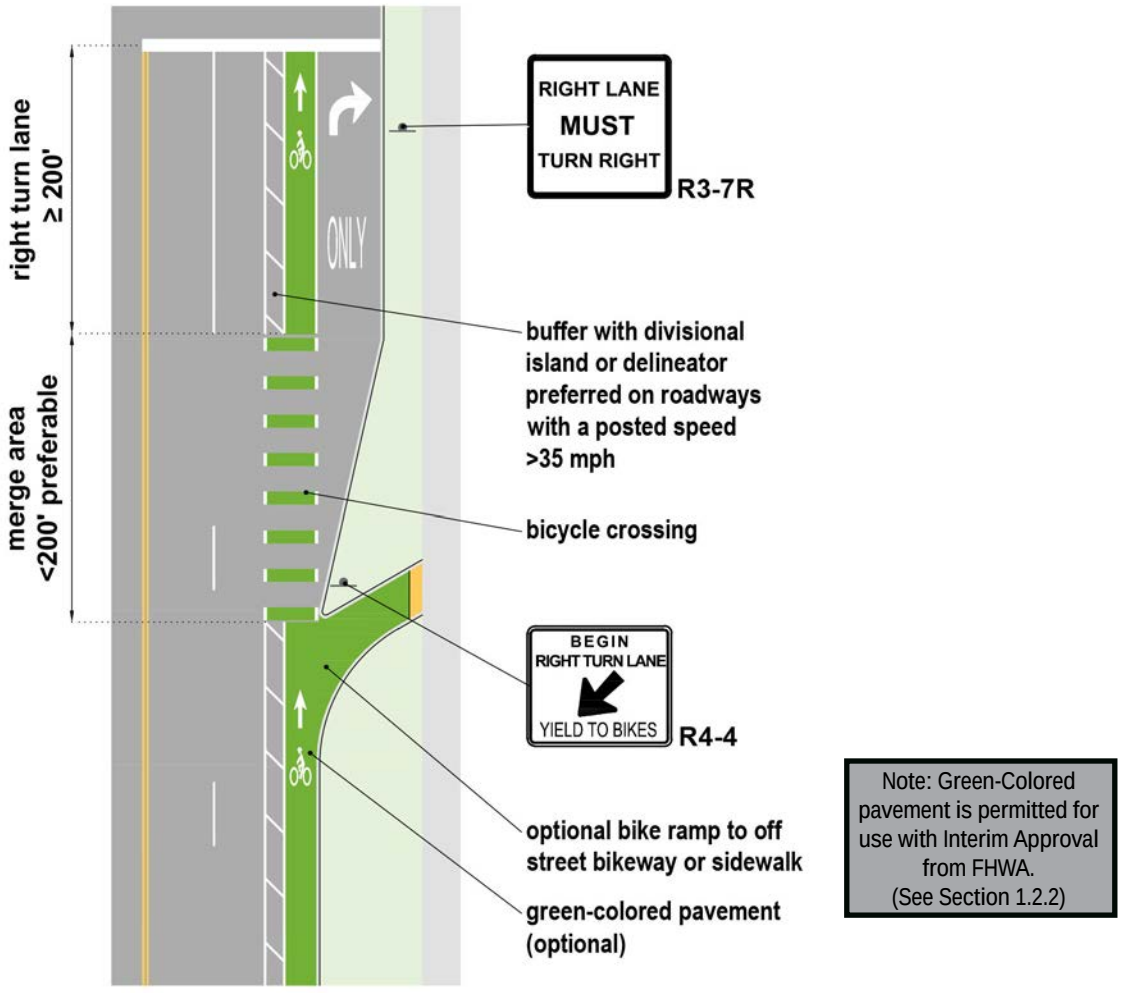
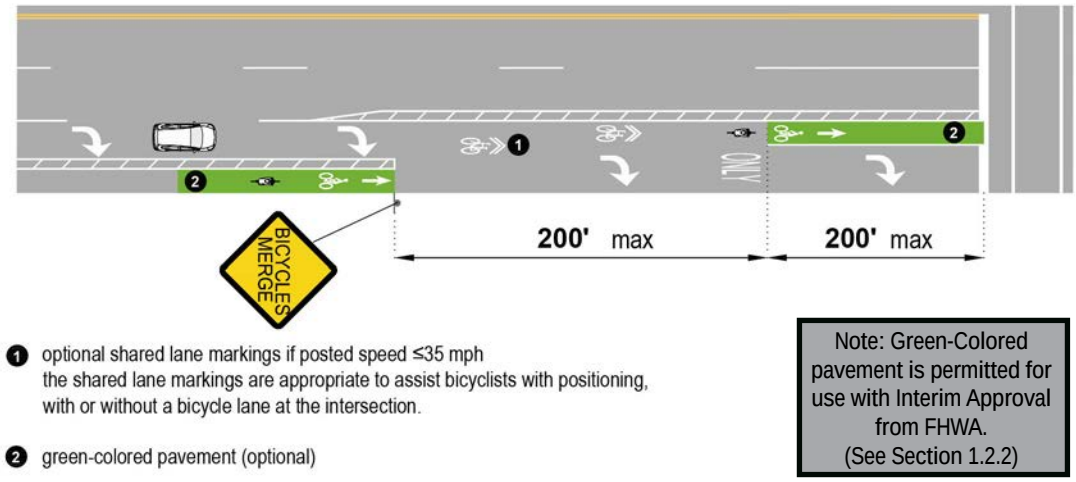


Figure 6-39: Through Lane Drops to Right Turn Lane with Bike Lane


ONLY
BICYCLES MERGE
200' max
200' max
1 optional shared lane markings if posted speed ≤35 mph
the shared lane markings are appropriate to assist bicyclists with positioning, with or without a bicycle lane at the intersection.
2 green-colored pavement (optional)
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA.
(See Section 1.2.2)

Where buffered bike lanes or bike ramps to an off-street bikeway or sidewalk are not feasible for roadways with operating speeds greater than 35 mph or right turn lanes that exceed 200 ft. in length, the bike lane may remain along the curb until it is within 400 ft. of the intersection, at which points the bike lane should transition to the left side of the right turn lane, as shown in Figure 6-39.

Through Lane Transitions to a Right Turn Only Lane

Figure 6-39 shows an intersection where a through travel lane becomes a right turn only lane or an auxiliary lane. In this scenario, the bicyclist must transition to the left side of the turn lane. This is a challenging maneuver for bicyclists, and it increases crash risk as traffic speeds exceed 30 mph and motorist volumes increase. To compensate for this, the bike lane should remain along the curb until it is within 400 ft. of the intersection. The bike lane drops at this point and is re-introduced on the left side of the right turn lane. Design treatments should be selected based on the operating speeds:

- Operating speeds less than 35 mph - shared lane markings may be used to delineate the likely path of travel of bicyclists transitioning to the shared lane and then into the bike lane. The bike lane should not be striped diagonally across the travel lane, as this inappropriately suggests to bicyclists that they do not need to yield to motorists when moving laterally. In this situation, the BEGIN RIGHT TURN YIELD TO BIKES (R4-4) sign should not be used, since bicyclists are the users who need to yield as they are weaving across the path of motor vehicle traffic. A BICYCLE warning sign (W11-1) or BICYCLES MERGE sign should be placed where the curb side bike lane ends.
- Operating speeds over 35 mph - a bicycle ramp should be considered to allow bicyclists to exit the roadway, if desired, to an off-street bikeway or sidewalk prior to the merge area.

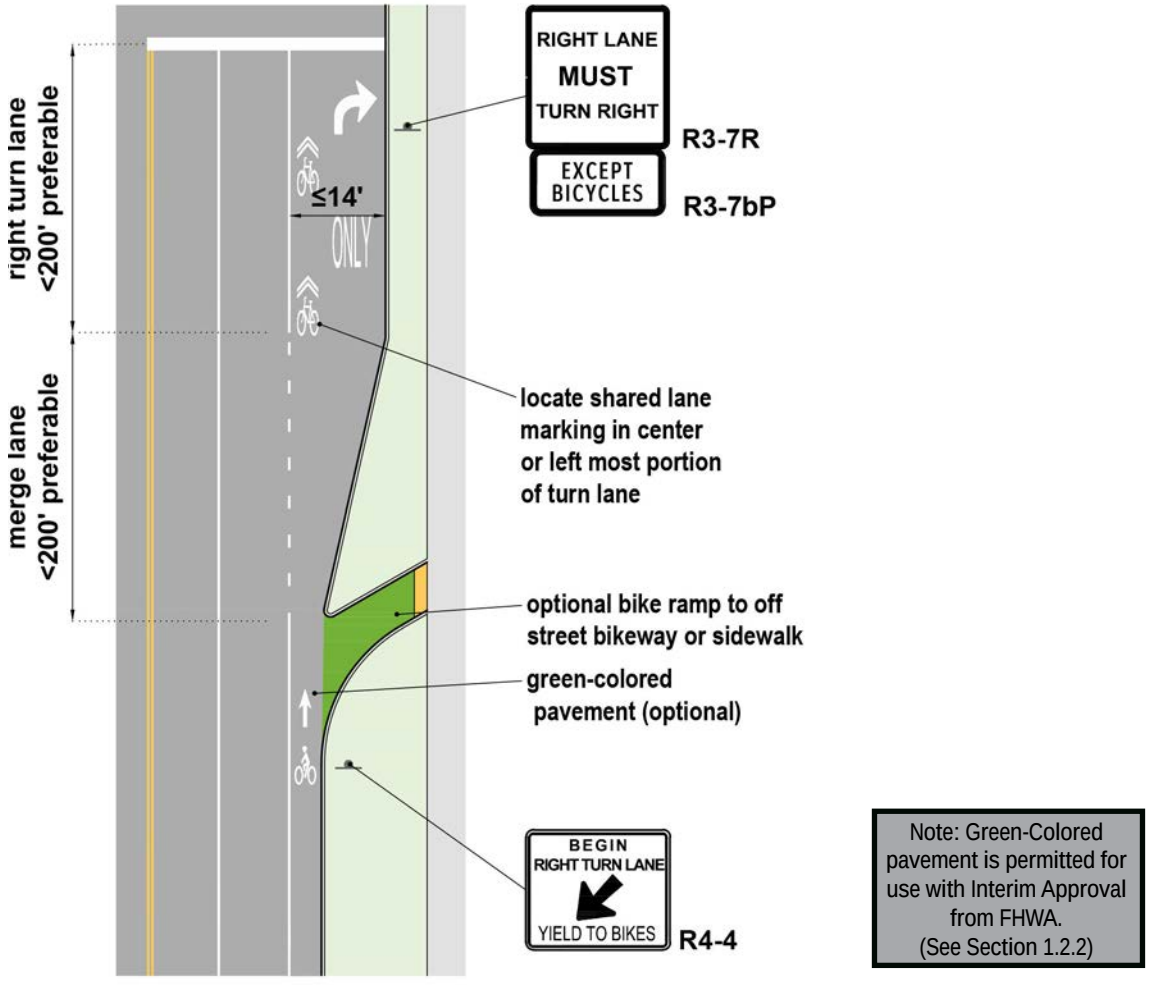
Bike Lane Ends to Develop a Right Turn Lane

If there is insufficient space for a bike lane and a right turn only lane, designers must select from three primary design alternatives. Bicyclists often prefer to operate within the lane that has a lower

traffic volume, experiences less queueing, and has lower operating speeds than the adjacent lane. Designers should select the treatment that maximizes bicyclist safety and comfort:

- Bike Lane Transitions to a Shared Right-Turn Lane - If the right turn only lane is best suited for bicyclists, the adjacent travel lane should be narrowed to the minimum width allowed by the L&D Manual Volume 1 to maximize the width of the turn lane for shared operation. At locations where the right turn lane is 14 ft. or less in width and posted speeds are less than 35 mph, shared lane markings may be located within the center or left-most portion of the turn lane (See Figure 6-40).
- Bike Lane Transitions to a Shared Through Lane - At locations where the right turn lane experiences extensive or frequent queuing or there is no bike lane present on the downstream side of the intersection, and has operating speeds below 35 mph, the shared lane markings may be located within the right-most through lane instead of within the right-turn lane. In these locations, the shared lane markings should be located following the guidance provided in Section 6.3.1 and Figure 6-3.

Figure 6-40: Example Right Turn Only Lane with Shared Lane Markings



- Bike Lane Transitions to an Off-Street Bikeway or Sidewalk - At locations where operational speeds exceed 35 mph or motorist volumes exceed 150 turning vehicles per hour, a bicycle ramp should be considered to allow bicyclists to exit the roadway to an off-street bikeway (separated bike lane or side path) prior to the termination of the bike lane.

Dual Right Turn Only Lanes

Avoid installing dual right turns on streets with bicycle lanes. If dual right turn lanes are necessary to accommodate heavy right-turn volumes, a designer should transition the bike lane to a separated bike lane or side path in advance of the intersection (see Figure 6-36). The high right turn volumes will require the provision of a separate bike crossing phase (see Chapter 8).

If the bike lane cannot be transitioned to a separated bike lane, shared lane markings may be located in the adjacent through lane if posted speeds are less than 40 mph.

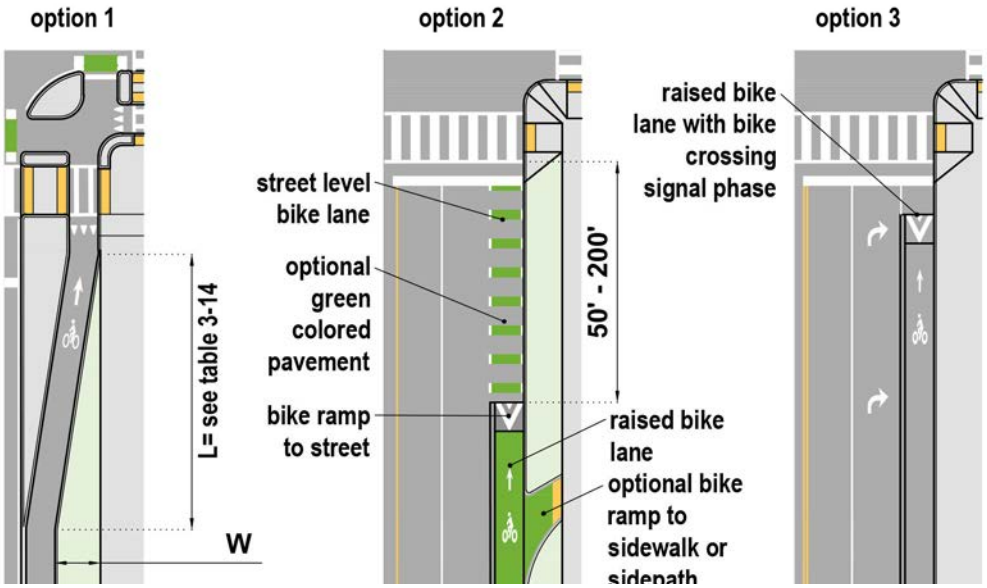
6.5.4. Raised Bike Lanes at Intersections

At locations where bike lanes are raised and located near adjacent travel lanes, it will be necessary for the raised bike lane to transition to a street level bike lane, shared lane, or to a sidewalk, side path or separated bike lane (see Figure 6-41).

It is preferable to transition the raised bike lane to bend away from the travel lane to form a protected intersection where space allows to minimize conflicts with turning motorists (Option 1).

Where it is determined to transition the raised bike lane to a standard bike lane or shared lane, that transition should occur 50 ft. to 200 ft. prior to the intersection (Option 2). A bike ramp should be considered to allow bicyclists to transition to the adjacent sidewalk or side path at locations where bicyclist may encounter high volumes of motorized traffic.

Figure 6-41: Intersection Approach Options for Raised Bike Lanes



Where protected intersections are not feasible, the raised bike lane should transition to street level. It is preferable for the raised bike lane to continue to the intersection and return to street level on a ramp within 10 ft. of a pedestrian crosswalk (Option 3). This option is only applicable when the bike movement is phase separated (see Chapter 8).

6.5.5. Counter flow Bike Lanes Intersection Design

At intersecting streets, alleys, and major driveways, DO NOT ENTER (R5-1) signs and turn restriction signs should include a supplemental plaque reading EXCEPT BICYCLES to establish that the street is two-way for bicyclists and to remind motorists to expect two-way bicycle traffic. At traffic signals, signal heads and suitable bicycle detection measures should be provided for counter flow bicyclists. If bicycle specific lenses are not used, a supplemental plaque reading BICYCLE SIGNAL may be needed beneath the signal to clarify its purpose. Bicycle crossing may be marked to further emphasize the counter flow movement of bicyclists to motorists.

Figure 6-42: Signing for Counter-flow Bike Lanes

Counter-flow transitions should normally occur at intersections or locations where bicyclists may return to normal two-way travel or naturally transition to the correct side of the street in another bikeway. If transitions are not made at logical locations, bicyclists may continue to ride counter flow in a shared lane, in a bicycle lane, or on a sidewalk which can substantially increase their crash risk.

6.5.6. Bicycle Boulevard Intersections and Crossings

Low-stress Intersection Crossings

An important principle of bicycle boulevards is to ensure that street crossings maintain the low-stress nature of the bikeway with minimal delay. Many of the intersections a bicyclist will cross will be local streets crossing other local streets. These are commonly all-way or two-way stop or yield-controlled, fully uncontrolled, or fully uncontrolled with traffic circles (see Chapter 7). Frequent stopping along a bicycle boulevard can significantly increase the bicyclist's total ride time and may result in reduced stop sign compliance where stops are closely spaced and crossing traffic volumes are low. For a bicycle boulevard to function as an alternative route to a parallel arterial, it should provide a similar travel time for the bicyclist as they would experience on the parallel arterial. In many cases, achieving this outcome may involve intersection control changes along the bicycle boulevard.

Traffic Controls for Minor Street Crossings:

- Limit locations where stop control is used on the bicycle boulevard to less than one location per half mile (in the direction of travel along the bicycle boulevard). Yield controls are preferable to stop controls as it allows bicyclist to slow and assess the cross traffic without having to stop and restart.
- On long corridors with a frequent application of all-way or two-way stop control, efficiency of the bicycle boulevard can be improved by removing stop controls on the bicycle boulevard and requiring the cross street to stop or yield, or by utilizing mini-roundabouts.
- Parking restriction signs may be necessary to provide the required sight distance at intersections where stop signs are removed or where yield control is provided.
- Consider supplementing STOP or YIELD signs with either CROSS TRAFFIC DOES NOT STOP (W4-4P) signs and/or Bicycle Guide Signs. When used, Bicycle Guide Signs should be installed on a separate post than the STOP sign.

Designers should be aware that the removal of stop signs can result in increased motor vehicle speeds and volumes. When bicycle boulevards run parallel to a congested arterial or are the only route through an area with few connecting streets, it may attract cut-through motorized traffic. Designers should consider traffic calming or diversion treatments to discourage or prevent increased traffic volume, speeds, or both (see Chapter 7).

Traffic Controls for Major Street Crossings:

Major street crossings along bicycle boulevards can be significant barriers. At intersections where a bicycle boulevard crosses an arterial road, or any other major road where the bicycle boulevard is stop- or yield-controlled, an uncontrolled crossing of the major roadway is common. Where traffic signals are not present, additional crossing measures may be needed to ensure bicyclists can continue along the route. Designers should ensure that there are sufficient crossing opportunities (see Table 6-8) and apply appropriate countermeasures as needed (see Section 6.4). Chapter 8 provides design guidance for beacon and signal countermeasures.

Bicycle boulevards are commonly used by families with children because they often originate in neighborhoods and provide connections between neighborhoods. At major streets, bicycle boulevard crossings may also be used by pedestrians. For these reasons, intersection crossings should assume pedestrians are crossing and include crosswalk markings, along with other appropriate design measures to accommodate pedestrian and bicycle crossings. Designers should be guided by the following performance criteria when evaluating and designing bicycle boulevard crossings at major intersections:

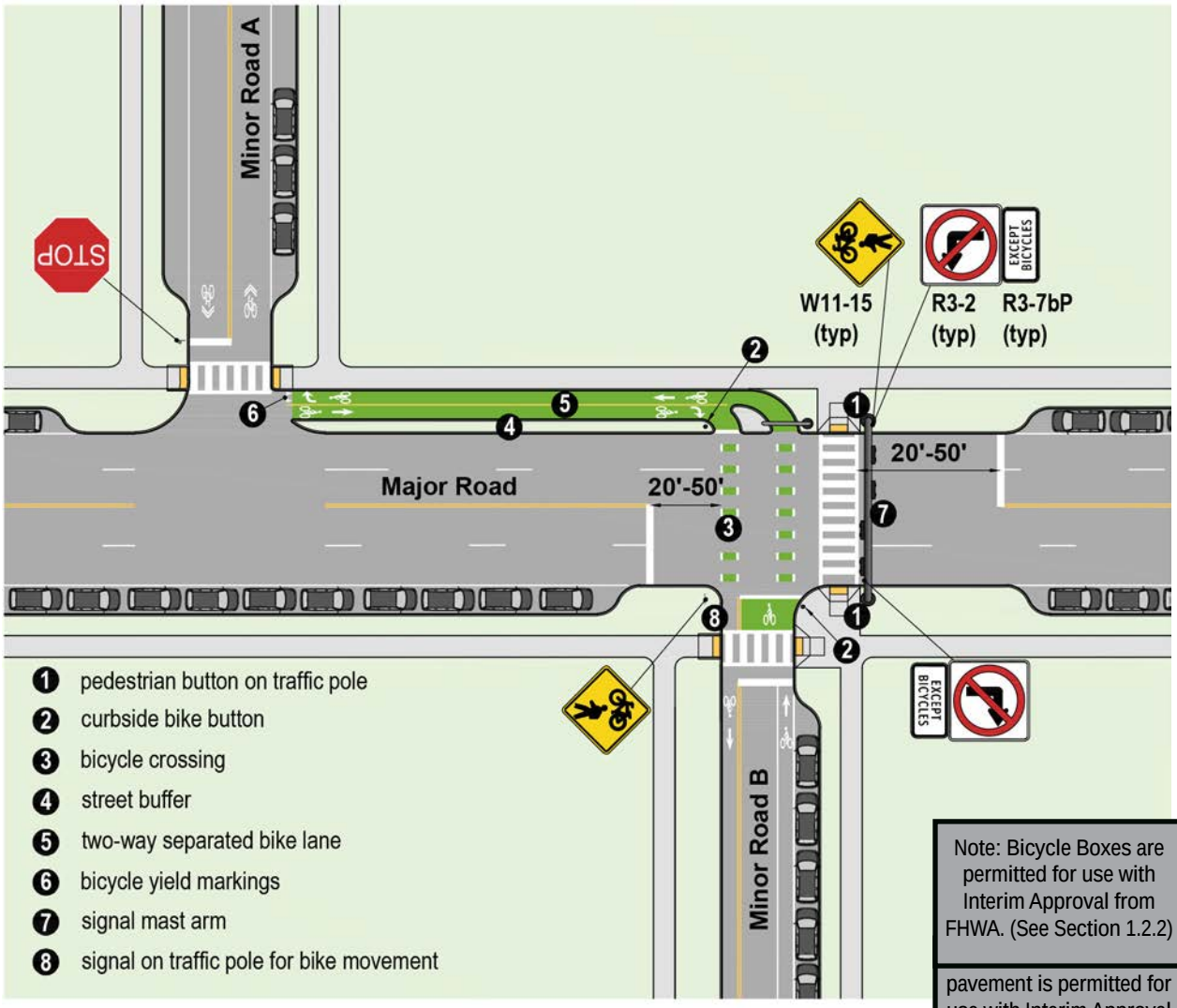
- Crossing time and acceleration should accommodate pedestrians and child bicyclists (Section 3.3.1 and Section 3.5.2 - Case D)
- Sight distance eye height should be based on recumbent bicyclist (Section 3.5)

In some instances, active beacons or traffic signals may be present to control the major street. At intersections with bicycle boulevards, it may be desirable to allow coordinated traffic signals to operate on half signal cycle lengths or to operate in “free” or uncoordinated mode during off-peak hours to reduce delays for bicyclists and provide frequent service (see Chapter 8).

Offset Intersections:

Along a bicycle boulevard, there may be discontinuities in the street grid. In order to continue, a bicyclist may be required to turn or travel for a brief distance on a roadway with higher motorist volumes and/or speeds. Without comfortable crossing treatments, offset intersection with these streets become a barrier along the corridor. In general, designers should select a bikeway for the major street based on the bikeway selection criteria identified in Figure 3-3 and follow the guidance for traffic control devices at major crossings in this section. Example connections could be a bicycle lane with two-stage turn boxes (Section 6.5.1) or a two-way separated bike lane or side path connection as shown in Figure 6-43.

Figure 6-43: Example of Connecting Off-Set Bicycle Boulevard Segments Using Two-Way Separated Bike Lanes



6.5.7. Paved Shoulder Intersection Design

Designers can transition a shoulder to a bicycle lane prior to intersections and driveways, and then transition back to a paved shoulder. Figure 6-44 shows an example of introducing a bike lane at an intersection where a right turn lane is present. For instances where a dedicated right turn lane is not present, see Section 6.5.3. Designers should follow signing and striping design in Section 6.3.4 and 6.5.3. Transitioning a paved shoulder to a separated bikeway at intersections may be desirable at locations near high-speed exit and entrance ramps to highways, or along high-volume, high-speed rural arterials with long deceleration, and right turn lanes where on-street bike lanes are not a preferred treatment.

When paved shoulders are not transitioned into bicycle lanes, bicyclists crossing an intersection from the paved shoulder or merging into the adjacent travel lane to turn left, continue straight, or turn right on to a roadway without a shoulder must yield to all vehicles within the roadway. As noted previously, the yielding requirements for vehicles traveling along the paved shoulder may not be clear to all roadway users. At a minimum, a regulatory sign reinforcing Ohio state law should be posted stating “BICYCLIST ON SHOULDER MUST YIELD” when the paved shoulder is wide enough to allow for bicycle use and it is a designated bikeway, such as a state and U.S. bicycle route, or where bicyclists are expected. The paved shoulder striping should not taper towards the cross street at intersections, but it can transition to a dotted edge line where motorists are expected to use the paved shoulder to begin their turning movement. Figure 6-44 shows both of the above described conditions for typical paved shoulder designs to accommodate bicycling.

Bypass lanes at T-intersections of two-lane roadways can be incorporated, so as to facilitate the passing of motorists stopped to make left turns onto intersecting roads. Where this is done on a highway with paved shoulders, at least 4ft. needs a space of shoulder pavement should be carried through the intersection along the outside of the bypass lane and designated as a bike lane. This is especially critical on roadways with higher volumes and operating speeds where bicyclists operating on the shoulder are likely to be in conflict with bypass lanes. See Figure 6-45.

Figure 6-44: Example Paved Shoulder Markings to Accommodate Bicycling

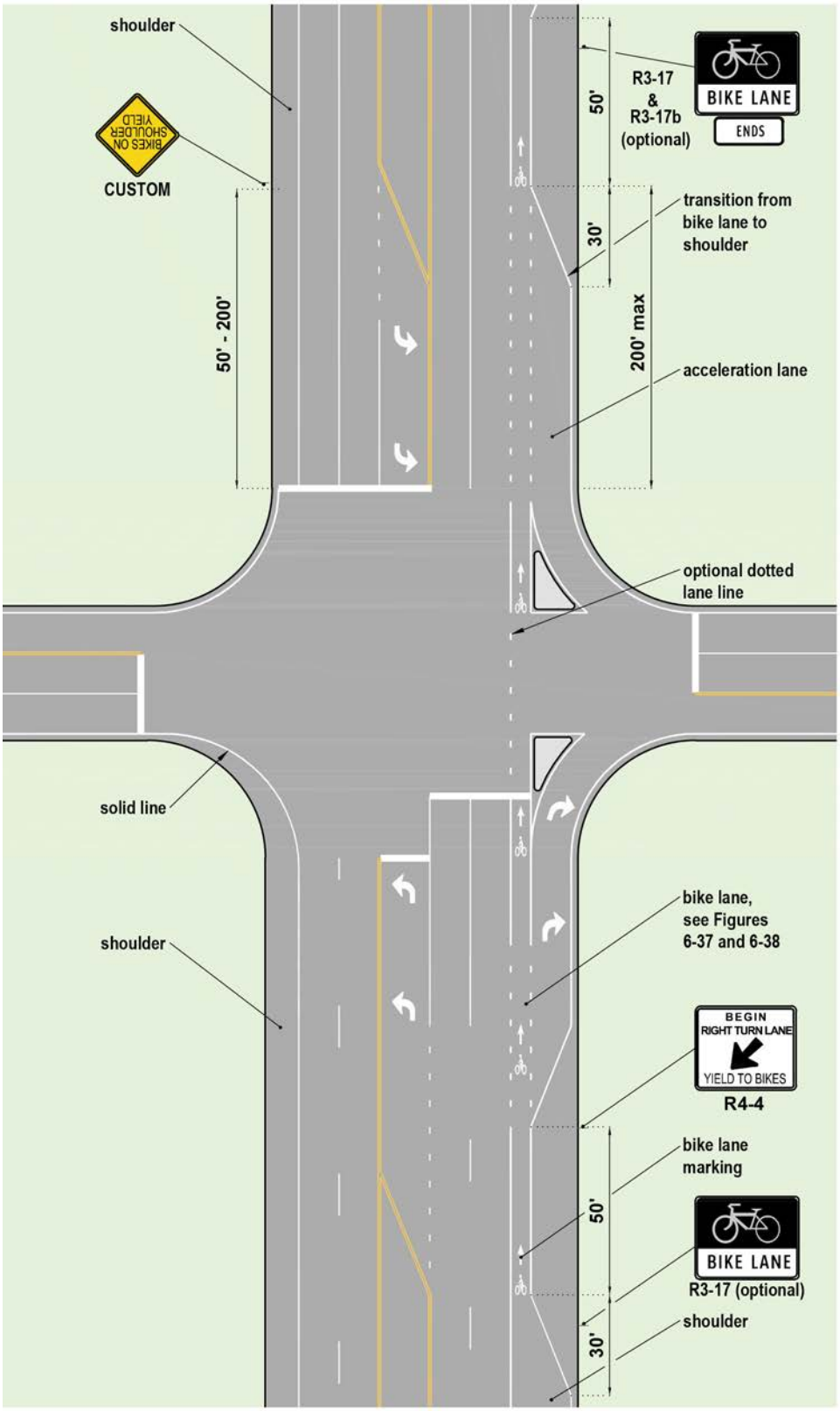
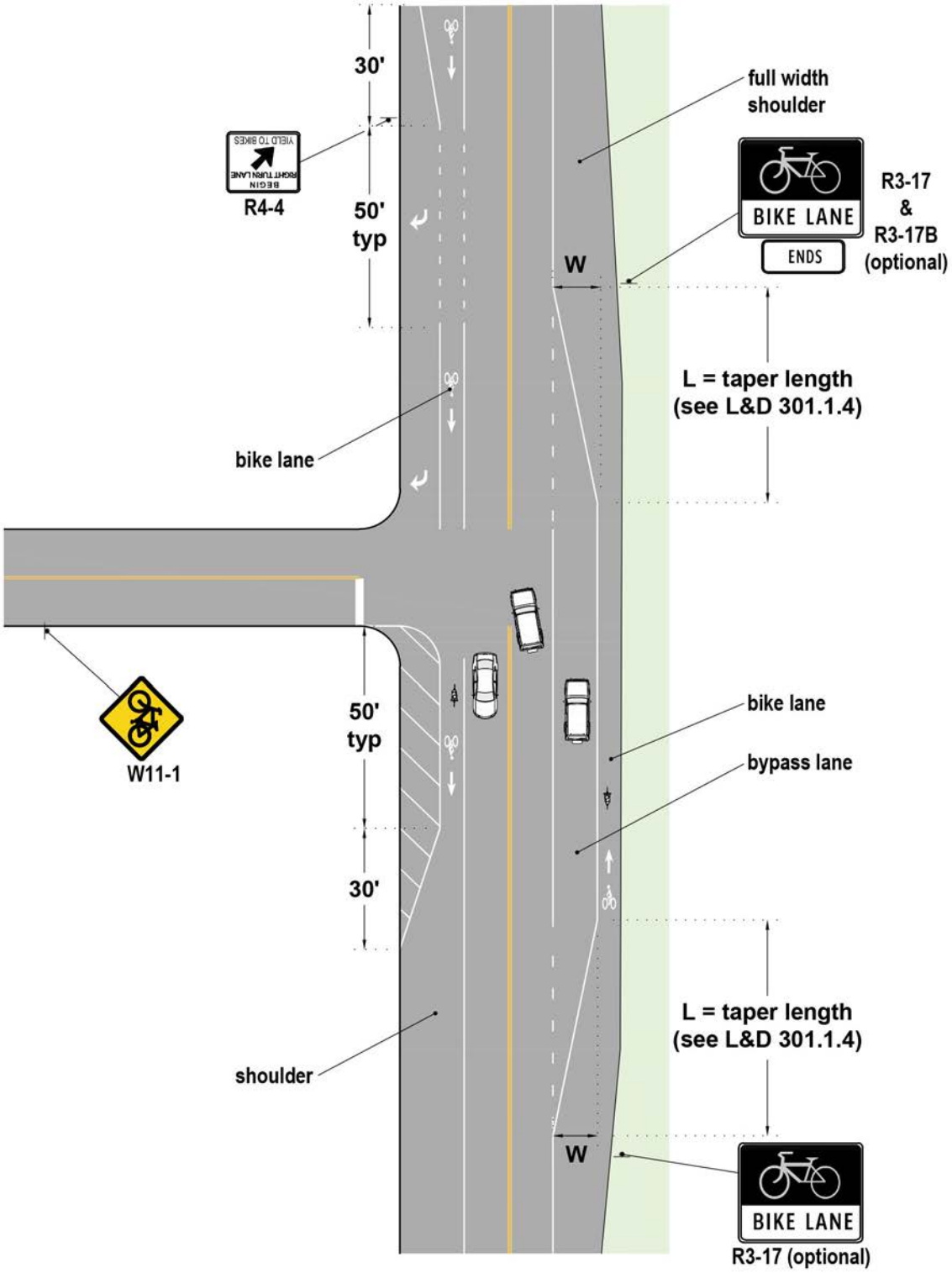


Figure 6-45: Motorist Bypass Lane with Bicycle Lane



6.5.8. Driveway and Alley Crossings

When on-street bike lanes cross driveways, the bike lane may be continued with solid white lines, if driveway volumes are low, or bicycle crossing markings may be provided at higher volume driveways. Table 6-11 identifies treatments for roadways based on motor vehicle volumes with the goal of both reinforcing right of way operations and slowing turning motorists crossing bikeways as conflicts increase. Driveway volume ranges shown in Table 6-11 should be used as a guide and may be adjusted based on land use context and roadway characteristics.

For all driveways, the design of the intersection between the driveway and a separated bike lane or side path should clearly communicate that bicyclists and pedestrians have the right of way by continuing the surface treatment of the bikeway across the driveway.

Where separated bike lanes or side paths intersect with high-volume driveways, crossings should be designed according to the protected intersection design principles (see Sections 6.5.1 and 6.5.2). At driveways where it is not possible to provide a protected intersection, or where there are other constraints or safety concerns, designers should take additional measures to increase the visibility of bicyclists to turning motorists, and to reinforce yielding behaviors. Some or all the following measures can be taken:

Table 6-11: Driveway & Alley Treatments along Roadways

Driveway Volume	Markings*	Elevation Considerations	Diveway Design Considerations
<200 veh/day	Bike lane markings should be maintained across driveway. Bike Crossing Markings may be used	Bike lane may be located at any elevation	A concrete driveway apron should be used
200-500 veh/day	Bike Crossing Markings should be used. Green-colored markings are allowed	Bike lanes may be located at any elevation	A concrete driveway apron should be used
>500 veh/day	Bike Crossing Markings should be used. Green-colored markings should be considered	Bike lanes may be at any elevation, but intermediate- or sidewalk-level bike lanes should be considered	A concrete driveway apron may be used. Where separated bike lanes or sidepaths are provided, the street buffer width should be between 6 and 16.5 ft.

*Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

- Raised crossings for bicyclists and pedestrians should be considered to increase motorist yielding behavior. See Chapters 4 and 7.
- Sight distances should be kept clear to ensure motorists exiting the driveway can see oncoming bicyclists, pedestrians, and motorists before leaving the driveway, and that motorists entering the driveway can see bicyclists and pedestrians approaching the driveway entrance and yield appropriately. Designers must consider if motorists will be permitted to block a separated bike lane to view approaching motor vehicle traffic (see Section 3.5.2 – Case C).
- Designers should minimize the width of driveways and consider access management strategies along separated bike lane routes to minimize the number and frequency of driveway crossings.

For corridors with on-street parking and commercial driveways spaced 100 ft. apart or less, designers should consider eliminating on-street parking between these driveways to maximize sight distances. For higher-volume commercial driveways, adjacent on-street parking must be eliminated to provide the adequate sight distance (see Section 3.5).

6.6 Overcrossings and Underpasses

As discussed in Chapters 4 and 5, grade-separated crossings may be necessary for bicyclists to cross common barriers such as freeways, arterials, and railroads. Designers should refer to Section 4.7 and 5.4 for details and design considerations.

6.7 Work Zone Bicycle Accommodations

Construction projects often disrupt the public's mobility and access. Proper planning for bicyclists through and along work zones is as important as planning for motor vehicle traffic. The OMUTCD (6A.01) states that the needs and control of all road users (motorists, bicyclists, and pedestrians) through a temporary traffic control zone shall be an essential part of highway construction, utility work, maintenance operations, and the management of traffic incidents. Bicyclists should be expected on all roads unless prohibited (e.g., limited access highways), therefore work zone treatments such as temporary lane restrictions, detours, and other traffic control measures should be designed to accommodate bicyclists.

Guidance for providing bikeways through or around work zones is discussed in the ODOT *Traffic Engineering Manual* and the OMUTCD. If a bicycle detour is needed, a route with similar or lower traffic stress should be provided. ODOT's online Level of Traffic Stress calculation tool includes pre-calculated values for level of traffic stress for the State & US Bike Route System and may be used for this detour evaluation.

Sections 670-2 of the TEM notes that "if the temporary traffic control zone affects the movement of bicyclists, adequate access to the roadway or shared use paths shall be provided." OMUTCD Section 6G.05 addresses work affecting pedestrians and bikeways. OMUTCD Chapter 6D and Sections 6F.74 and Chapter 603 provide additional information regarding steps to follow when pedestrians and bikeways are affected by the worksite.

When feasible, designers should incorporate the following recommendations into project construction plans:

- Maintenance of bicycle travel should be included whenever the need for temporary traffic control is being considered. Designers should determine how to maintain existing bikeways during construction and details should be provided in the MOT design portion of the project plans. Options include accommodating bicyclists through the work zone or providing a suitable alternate route with the least amount of detour necessary. It is preferable for the alternate route to direct bicyclists to a bikeway that is equal to or lower in traffic stress than the existing route.
- Similar to other vehicular traffic, work zones should be compatible with bicycle travel. Work zone concerns for bicyclists may include road or path closures, sudden changes in elevation, construction equipment or materials, and other unexpected conditions. Providing bicyclists access through or around the work zone may result in the need for the construction of temporary facilities, including paved surfaces, structures, signs, and signals. The OMUTCD includes appropriate mode-specific detour guidelines in the section on temporary traffic controls.
- Work zone signs, construction vehicles, and other related construction materials should not be stored or placed within bikeways or on sidewalks that are open for use. Workers who routinely perform maintenance and construction operations should be aware of these considerations.
- For sections of separated bike lanes or shared use paths which are closed to bicyclists, advanced warning is necessary to allow bicyclists sufficient time and space to transition out of the bikeway. This may require construction of temporary curb ramps to transition bicyclists to a street or sidewalk. It is also preferable to maintain physical separation from traffic where feasible, as separated bike lanes and shared use paths often attract people who are not comfortable operating in mixed traffic.

Chapter 6 Endnotes

1 Hess, G. and M. N. Peterson. "Bicycles May Use Full Lane" Signage Communicates U.S. Roadway Rules and Increases Perception of Safety. *PLoS One*, Vol. 10, No. 8, 2005.

2 Teschke, K., M. A. Harris, C. C. Reynolds, M. Winters, S. Babul, M. Chipman, M. D. Cusimano, J.R. Brubacher, G. Hunte, S. M. Friedman, M. Monro, H. Shen, L. Vernich, and P. A. Cripton. Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study. American Journal of Public Health, Vol. 102, No. 12, 2012, pp. 2336-2343.

3 Schepers, J.P., P. A. Kroeze, W. Sweers, J.C. Wüst. Road Factors and Bicycle-Motor Vehicle Crashes at Unsignalized Priority Intersections. *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 853-861.

4 Zangenehpour, S., J. Strauss, L.F. Miranda-Moreno, N. Saunier. *Are Signalized Intersections with Cycle Tracks Safer? A Case-Control Study based on Automated Surrogate Safety Analysis using Video Data*. Accident Analysis and Prevention, Vol. 86, 2016, pp. 161-172.

5 Smith, R. L. and T. Walsh. Safety Impacts of Bicycle Lanes. In Transportation Research Record 1168. TRB, National Research Council, Washington, DC, 1988.

6 Schepers, J.P., P. A. Kroeze, W. Sweers, and J.C. Wust. Road Factors and Bicycle-Motor Vehicle Crashes at Unsignalized Priority Intersections. *Accident Analysis and Prevention*, Vol. 43, 2011, pp. 853-861.

7 Madsen, T., and H. Lahrmann. Comparison of Five Bicycle Facility Designs in Signalized Intersections Using Traffic Conflict Studies. *Transport Research Part F*, Vol. 46, 2017, pp. 438-450.

8 FHWA *Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Location*

9 FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations*

10 *Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord. National Cooperative Highway Research Program Report 562: Improving Pedestrian Safety at Unsignalized Crossings. NCHRP, Transportation Research Board, Washington, DC, 2006.*

CHAPTER 7: MOTOR VEHICLE FACILITIES SUPPORTING MULTIMODAL ACCOMMODATION

Chapter 7: Motor Vehicle Facilities Supporting Multimodal Accommodation

7.1 General

This chapter provides an overview of how typical roadway elements can be designed to support a multimodal transportation network. Other chapters in this Guide provide guidance on addressing pedestrian and bicyclist travel and behavior, whereas this chapter focuses on addressing motorist travel and behavior. Designers should consider all existing and planned modes during the design process. As discussed in Chapter 3, this process may require design flexibility when applying roadway design criteria.

7.1.1. Design Principles and Objectives

ODOT's mission is to provide safe and easy movement of people and goods from place to place. Based on existing data, crashes involving motor vehicles with pedestrians or bicyclists are disproportionately higher by volume than crashes only involving motor vehicles, and when crashes occur at conflict points with higher speeds the severity of injury increases. Roadway designers should address these systemic safety issues to reduce the frequency and severity of crashes where they are likely to occur.

Designers should refer to the Multimodal Planning Goals described in Chapter 2 for an understanding of the principles that guide active transportation planning, facility selection, design, and project prioritization.

7.2 Minimizing Turning Speeds at Intersection

Vehicle turning movements affect operations and safety at an intersection. If conflict points cannot be eliminated through signal phasing or grade separation, intersection design should minimize the speed differential between users at the points where travel movements intersect. The process for controlling the speed of right turning vehicles is described in Sections 7.2.1 through 7.2.6. For controlling left turning vehicle speed, see Section 7.2.7. Raised crossings may also be considered at intersections and have been shown to reduce turning vehicle speeds of both right and left turning vehicles (see Section 4.5.5).

7.2.1. Intersection Design and Check Vehicles

For roadways where the most common vehicle is a passenger car, delivery vehicle, or single unit truck, designing intersections to easily accommodate larger vehicles with large turning radii can negatively affect crossing distances, exposure to conflicts, speed of common turning vehicles, and can impact right-of-way or be inconsistent with the surrounding land use context. Similarly, using a smaller design vehicle at intersections regularly used by larger vehicles should be avoided because frequent operational challenges may occur, may lead to encroachment beyond the edge of pavement or curbline, and can lead to damage to infrastructure such as curb ramps, signs, or poles.

The L&D Manual Volume 1 Section 401.9 defines the two types of vehicles that must be considered at each intersection: Intersection Design Vehicles (IDV) and Intersection Check Vehicles (ICV). Figure 401-15a shows the recommended IDVs and ICVs along with their acceptable Degrees of Encroachment (DE) for ODOT roadways based on the functional classifications of the intersecting roadways. On many local roadways, particularly in residential areas, the design and check vehicles will be smaller than those stated in Figure 401-15a. In addition, where the intersection check vehicle is an emergency service vehicle, a greater degree of encroachment may be considered. Designers should check local policies for selecting IDV and ICV and adjust based on the roadway type and surrounding land use context.

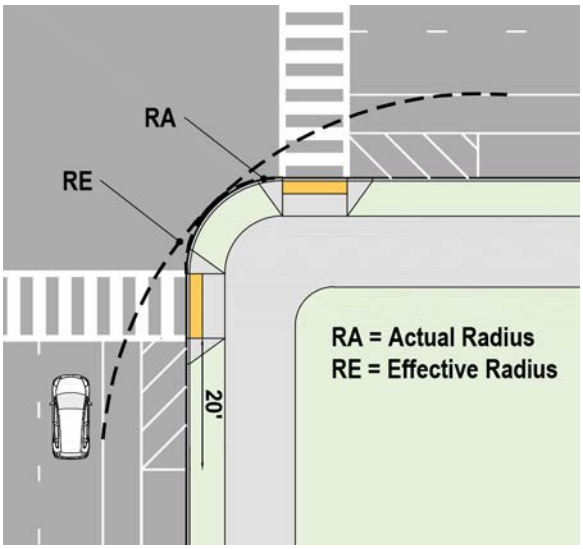
7.2.2. Turning Vehicle Design Speed

At both signalized and unsignalized intersections (including roundabouts), steps should be taken to ensure that turning speeds are kept low and that sight distance is not compromised for either the pedestrian, bicyclist, or motorists. While performing swept path analyses, the maximum recommended turning speed of the design and check vehicle is 10 mph.

7.2.3. Actual and Effective Curb Radius

Two distinct radii need to be considered when designing street corners. The first is the actual radius of the street corner itself, and the second is the effective turning radius of the selected IDV or ICV, see Figure 7-1. The effective turning radius is the radius needed for a turning vehicle to clear any adjacent parking lanes and/or to align itself with its new travel lane. Using an effective turning radius allows a smaller curb radius than would be required for the motorist to turn from curb lane to curb lane.

Figure 7-1: Actual Corner Radius vs. Effective Turning Radius



7.2.4. Designing Intersection and Driveway Corner Radii

Designers should strive to provide the smallest appropriate corner radius for the given IDV and ICV, target turning speeds, acceptable lane encroachment, number of receiving lanes, and effective pavement width. In addition to discouraging higher turning speeds, smaller corner radii are preferred in order to better align curb ramps with pedestrian paths of travel and shorten crossing distances.

To achieve the smallest appropriate corner radius, designers should follow these strategies:

- Using vehicle turning software or turning template, designers should minimize the corner radius while accommodating the effective turning radius of vehicles.
- Where pedestrians or bicyclists are expected and the effective turning radius exceeds 15 ft., consider the following:
  - Push back the stop line of the receiving street beyond the minimum 4 ft. from crosswalks where appropriate. Ensure that any encroachment does not conflict with overlapping phases at signalized intersections. In general, stop lines should not be pushed back more than 30 ft. from crosswalks as motorist compliance may be diminished; however, the maximum distance from stop line to traffic signals cannot exceed the sight distance and clear zone requirements established in OMUTCD Chapter 4D.
  - Provide a truck apron to increase the effective radius of larger vehicles, including SU-30, while providing a smaller effective radius for the majority of vehicles (e.g., passenger car). See Section 7.2.5 for additional information and design guidance.
  - At skewed intersections and where truck aprons would exceed 15 ft., consider a channelized island as described in Section 7.2.6.
  - Consider a raised crossing to slow turning vehicles. See Section 7.8.3.

As described elsewhere in these guidelines, curb extensions are beneficial to pedestrians. It is acceptable to have a curb bulb with a larger curb radius that shortens crossing distances while accommodating large vehicles. For curbless streets, care should be taken at corners to ensure that proper design treatments are included to identify safer turning distances for large vehicles. Such treatments may include pavement coloring, different materials, and other features that provide a visual indication of the apex of the turn.

Flex delineator posts or engineered rubber curbs may be used as an interim treatment to reduce larger corner radii. When used, they should be placed at least 1 ft. offset from the turning radius of design vehicles at all intersections and driveways.

7.2.5. Truck Aprons

Truck aprons are most common within the center island of a roundabout but should also be considered at intersection corners to accommodate the turning characteristics of larger vehicles while slowing the turning speeds of smaller design vehicles. The truck apron must be designed to be mountable by larger vehicles to accommodate their larger turning radius while smaller vehicles follow the smaller radius along the outside edge of the truck apron, see Figure 7-2.

The outside edge of a truck apron (i.e., closest to the travel lane) is constructed using a mountable curb and should be designed so that passenger vehicles follow this mountable curbline at the desired 10 mph speed. Larger vehicles, including SU-30, can traverse the truck apron if desired, but the control vehicle should be used to specify the effective radius.

The truck apron is part of the motorist travel way. Truck aprons shall not extend through bike lanes or crosswalks unless they are designed to accommodate these users, and bicycle stop bars and pedestrian accommodations (e.g., curb ramps, crosswalks) must be placed to prevent these users from waiting in the travel way. Colored concrete and/or pavement markings should be used within the truck apron area to provide a visual contrast from the adjacent roadway and sidewalk. This communicates to drivers of smaller vehicles that this is not an area to drive over. Where widths exceed 15 ft., the intended use of the apron may not be clear and designers may consider a channelizing island to limit the street crossing distance for pedestrians and bicyclists (see Section 7.2.6).

In retrofit conditions, a truck apron that extends all the way to the existing curbline may not be possible without significant stormwater system modifications. In these situations, truck pillows that maintain drainage along the existing curbline may be more practical and feasible.

See DWG 7-1 for additional design details for truck aprons and truck pillows.

An edge line should be provided along the outside edge of wider truck aprons and designers should consider reflective raised pavement markers, where appropriate, to ensure that the path of travel is visible. Gore markings may be installed on the truck apron itself, but this is often unnecessary if colored pavement is used, see Figure 7-3.

Figure 7-2: Typical Truck Apron Layout at a Protected Intersection

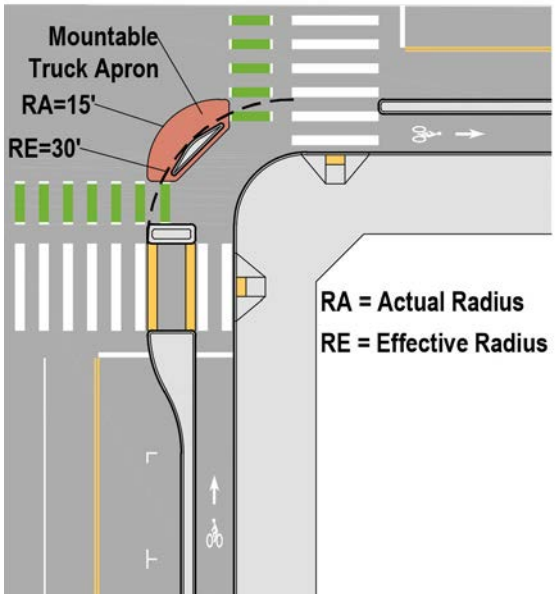


Figure 7-3: Truck Apron with Concrete and Pavement Markings (top) and Tiered Truck Apron with Colored Concrete (bottom)

Where buses are likely to traverse the truck apron with regularity (such as transit routes), truck aprons should be designed to allow the bus to complete the turn without traversing the truck apron. A tiered truck apron with a curb reveal from 0 to 1 inch can be constructed for use by buses while the second tier can be designed with a 3 inch curb reveal for use by larger trucks, see Figure 7-3.

7.2.6. Turning Lanes and Channelized Islands

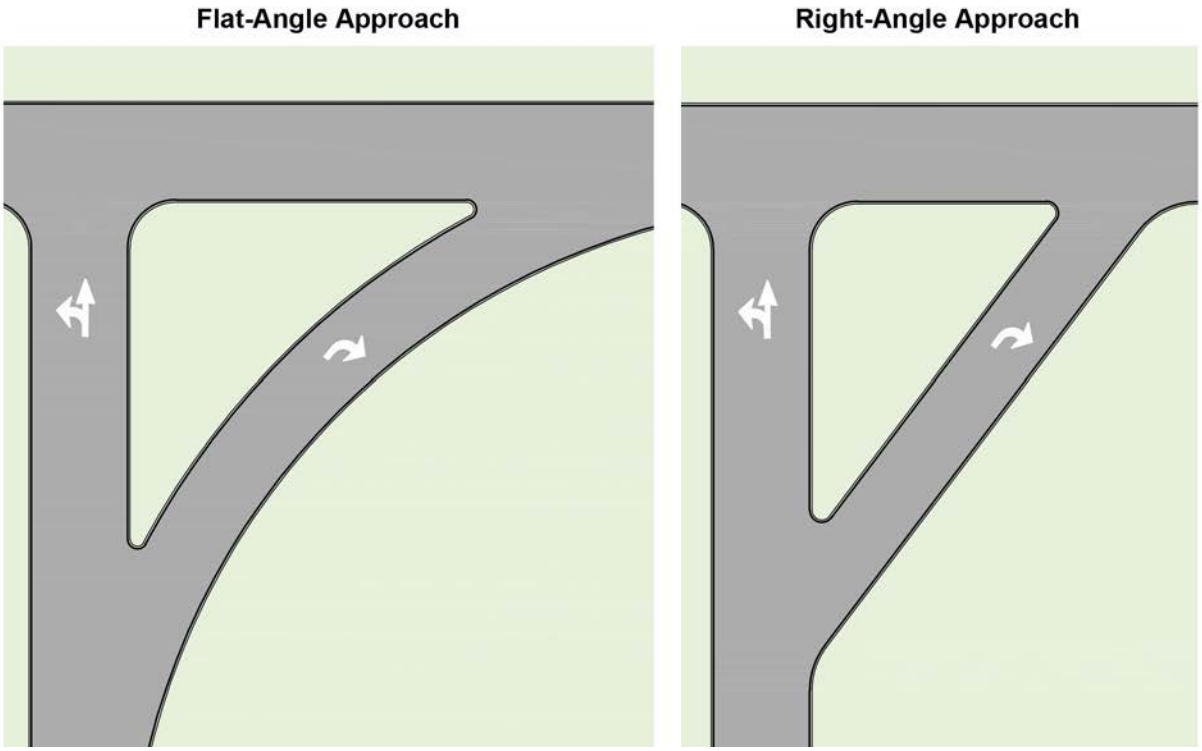
A channelized right turn lane may be preferable to a larger corner radius to decrease the street crossing distance for pedestrians and bicyclists. These are common at skewed intersections or other overbuilt roadways with large curb radii and cross-sections.

Where channelized right turn lanes are provided, it will be necessary to choose between a flat angle (> 140 degrees) or a right-angle (< 120 degrees) approach to the cross street (see Figure 7-4). To ensure the channelized right turn lane promotes motorists yielding at pedestrian and bicycle crossings, as well as to cross street motorists, a right-angle entry design is preferred. This design encourages lower turning speeds and improves the driver's view of people approaching crosswalks and motorists approaching from the cross street.

The use of flat-angle approaches should be avoided, except where:

- motorists have their own receiving lane on the cross street, and

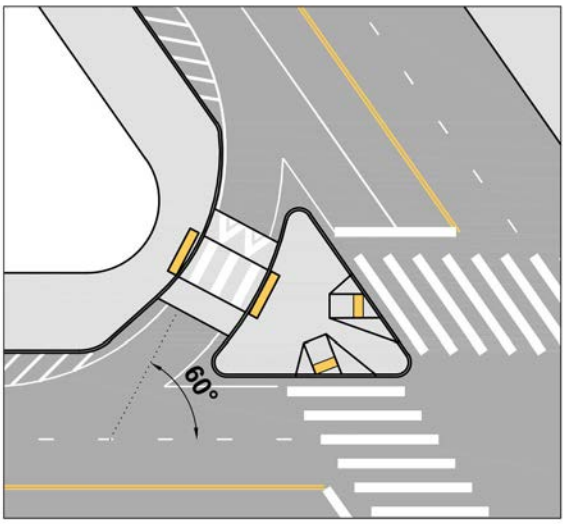
Figure 7-4: Channelized Right Turn Design Options



- higher turning speeds are necessary for safe merging onto the cross street, and
- it is needed to accommodate the turning path of the design vehicle (e.g., at skewed intersections), and
- pedestrian and bicycle crossings are not allowed or infrequent, or traffic controls devices are provided to control the conflicting motor-vehicle movement and facilitate pedestrian and bicyclist crossings.

A raised crosswalk (see Section 4.5.5) should be considered at channelized right turn lanes where motorists do not face stop or traffic signal control to encourage motorist yielding. They may also be beneficial at yield, stop, and signal control intersections where it is desirable to reduce encroachments into the crosswalk. When used at a channelized island, the crosswalk should be located to allow one vehicle to wait between the crosswalk and the cross street.

Figure 7-5: Raised Crosswalk Across Flat-Angle Approach Channelized Right Turn



L&D Manual Volume 1, Section 401.7.2, provides additional guidance on the design of channelized islands.

7.2.7. Median Islands and Hardened Centerlines

Chapter 4 discusses how a raised median island can be used to provide pedestrian refuge space to cross a major street. In that situation, a minimum of 6 ft. is required to accommodate a pedestrian or bicyclist waiting to cross the second portion of the crossing. When less than 6 ft. in width is available, designers can still provide a center median, also known as a hardened centerline, to channelize and slow the speeds of left turning motorists as they prepare to cross the path of pedestrians and bicyclists.

A hardened centerline is comprised of a painted centerline supplemented by flexible delineators, mountable curb, rubber curb, concrete curb, IN-STREET PEDESTRIAN CROSSING signs (R1-6), or a combination of these treatments. The dimensions of a hardened centerline will depend on the intersection geometry and vehicle turning radius. Hardened centerlines should be considered where higher-speed left turns occur concurrent with pedestrian and/or bicyclist movements, as they have been found to reduce the speed of left turning motorists by reducing the effective turning radius.[1] Hardened centerlines can be appropriate on both the departure roadway and the receiving roadway to control the left turning motorist path of travel. See Figure 7-6 and Figure 7-7.

Figure 7-6: Example of Hardened Centerline Applications with Flexible Delineators on the Departure Roadway and a Pedestrian Crossing Island on the Receiving Roadway

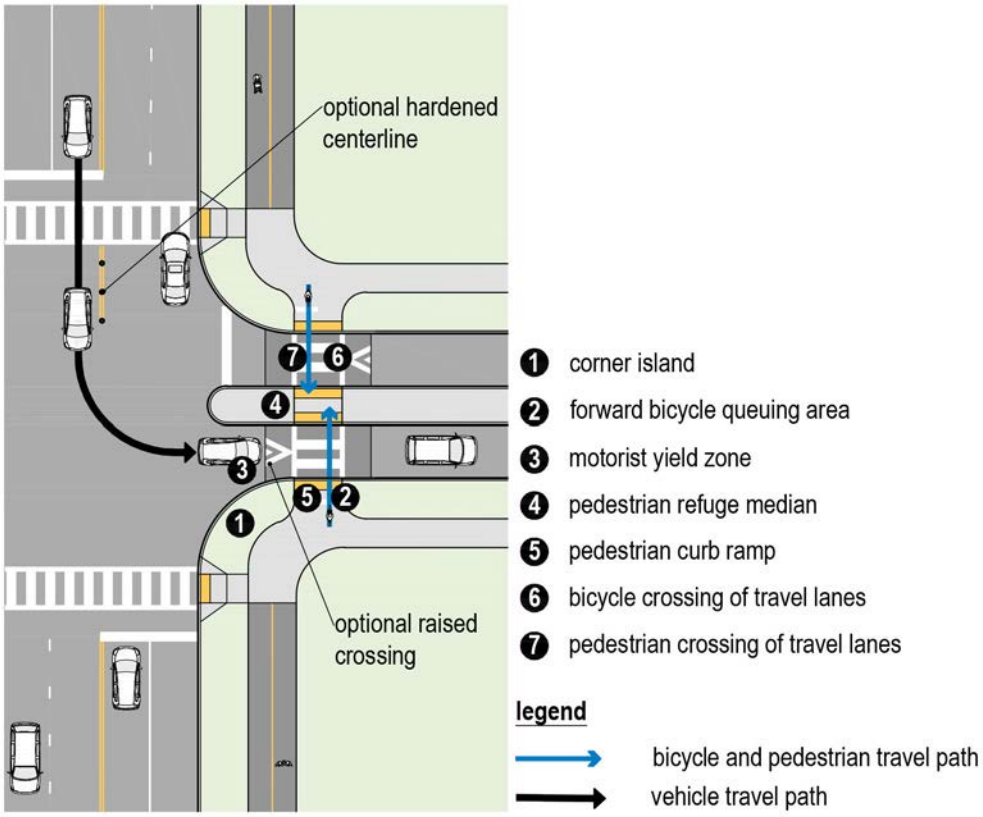


Figure 7-7: Flexible Delineators and Hardened Centerline to Control Turning Speed

7.3 Vehicle Travel Lane and Shoulder Widths

L&D Manual Volume 1, Section 301.1.2, Fig. 301-2 and Fig. 301-4, provide the lane widths for rural and urban areas, and Section 301.2.3, Fig. 301-3 and Fig. 301-4, provide guidance on shoulder widths for rural and urban areas.

When pedestrians or bicyclists are expected to be present, designers should use the minimum widths as described in the L&D Vol. 1 for travel lanes, on-street parking, and potentially shoulders. Deviations from the minimum lane and shoulder widths may be considered where appropriate to achieve the project goal(s). Narrow lane widths discourage higher operating speeds, reduce pedestrian crossing distances, and create spaces for sidewalks and bikeways. FHWA no longer considers lane and shoulder width as controlling criteria for roadways on the National Highway System (NHS) with less than 50 mph design speeds, allowing for increased flexibility to implement narrower lanes on those roadways. For roads on the National Network (or National Truck Network) a design exception for lane width is required if at least one 12 ft. lane in each direction cannot be provided. See Section 105.3 of the L&D Vol. 1 for more information. In retrofit situations where excess pavement cannot be reduced, travels lanes can be visually narrowed with pavement markings or contrasting materials. This space could be used for a buffer for bike lanes, a marked center median, or to provide space for a designated shoulder or bike lane.

In constrained settings, sidewalk or bikeway buffer zones could accommodate traditional shoulder functions of drainage, snow storage, and lateral support of pavement.

These concepts are further discussed in Section 7.5.2.

7.4 On-Street Parking Considerations

Section 6.3 provides details on the design and considerations of on-street parking in relationship to bicycle lanes. Guidance on parallel and angled parking is provided, as well as an overview of considerations for loading zones and accessible parking spaces. Where angled parking can be accommodated, back-in angled parking is preferred as it improves driver sight lines when exiting parking spaces. Additionally, back-in angled parking directs passengers exiting the vehicle back towards the curbline (i.e., the opened vehicle doors block access towards the street) which can beneficial to direct children exiting vehicles towards the sidewalk.

Sections 4.6 and 6.3.7 provide guidance for the design of accessible on-street parking spaces. Section 7.7 provides additional guidance on restricting parking near intersections, driveways, and crosswalks.

7.5 Reallocating Street Space

Streets and highways can be retrofitted to better accommodate bicyclists and other users by widening the roadway or by reallocating pavement to these users by reconfiguring the travel lanes. This approach can better balance the level of service for all travel modes by providing wider sidewalks, bike lanes, and buffers between bicyclists, pedestrians, and motor vehicles. Space can also be dedicated to plantings and amenity zones and reducing crossing distances.

When retrofitting roads for bicycle facilities, the width guidelines for bike lanes and paved shoulders (see Sections 6.3) should be applied. For additional information on retrofitting bicycle facilities on existing streets and highways see the FHWA Incorporating On-Road Bicycle Networks into Resurfacing Projects and the FHWA Road Diet Information Guide.

Retrofitting bicycle facilities on bridges presents special challenges because it may be impractical to widen an existing bridge. The guidance below for retrofitting bicycle facilities without roadway widening is applicable to existing bridges. Further guidance on accommodating bicyclists on bridges is presented in Chapters 5 and 6.

7.5.1. Retrofitting Bicycle Facilities by Widening the Roadway

Where right-of-way is adequate, or where additional right-of-way can be obtained, roads can be widened to provide the desired multimodal facilities. The design should follow the design principles discussed throughout this guide and ensure that widening the roadway does not result in increased vehicle speeds that may adversely impact bicyclists and pedestrians.

7.5.2. Retrofitting Bicycle Facilities Without Roadway Widening

In many areas, especially built-out urban and suburban areas, physical widening is impractical, and bicycle facility retrofits are constructed within the existing paved width. There are three methods of modifying the allocation of roadway space to improve bicyclist accommodation:

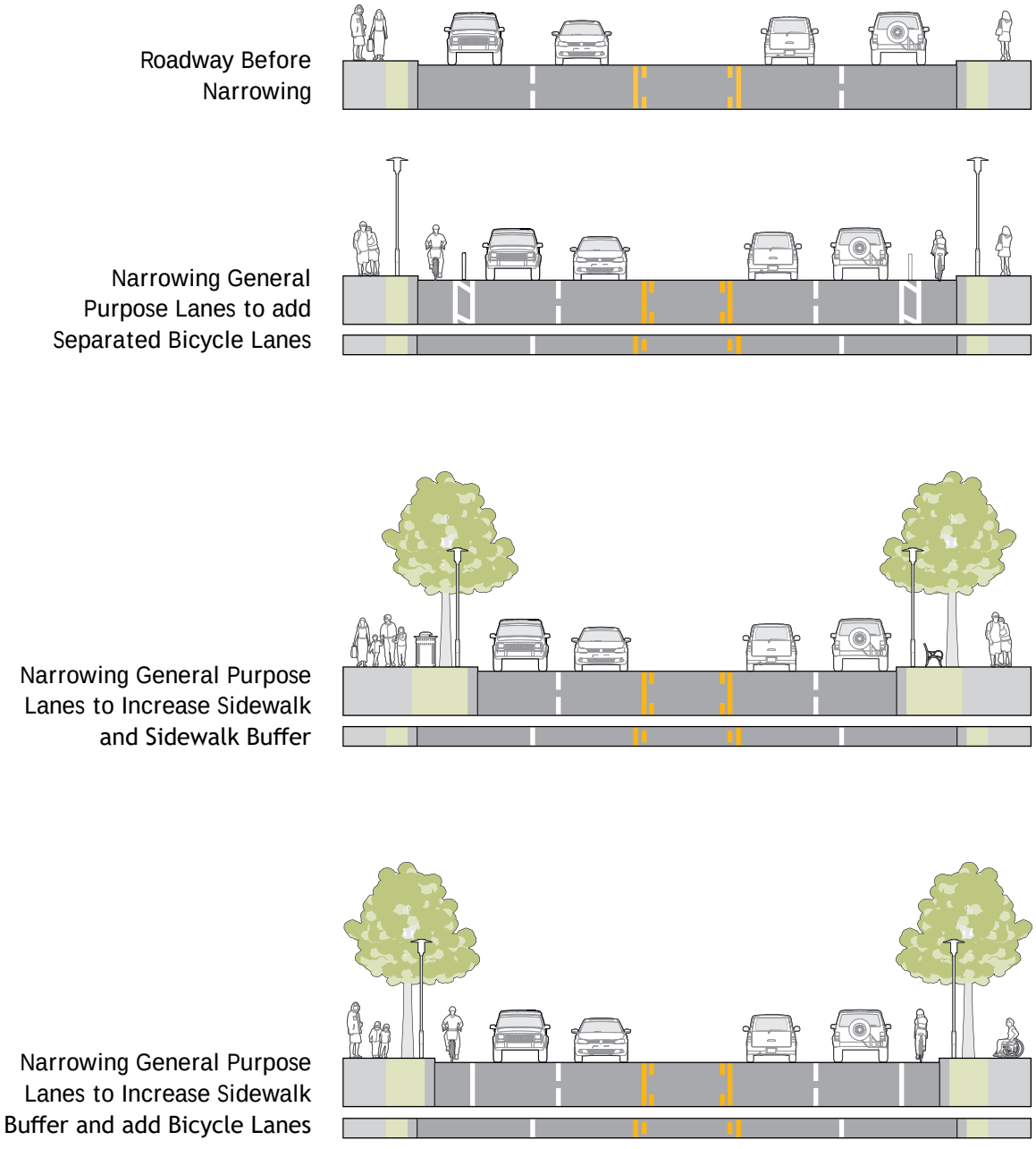
1. Reduce or reallocate the width used by general purpose travel lanes.
2. Reduce the number of general purpose travel lanes.
3. Reconfigure or reduce on-street parking, including parking lane width.

Travel lane widths can often be narrowed without any significant changes in levels of service for motorists. Before a reduction or reallocation in the number of travel lanes or their widths is considered, an operational study should be performed to evaluate the impact of the proposed changes on the level of service. One benefit is that bicycle LOS will be improved when adding a bicycle facility. Creating shoulders or bike lanes on roadways can improve pedestrian conditions as well by providing a buffer between the sidewalk and the roadway.

Lane Narrowing

Narrowing existing motor vehicle lanes may create enough space for separated bike lanes, widening sidewalks and buffers, or a combination of on-street bike lanes and enhancements to the pedestrian realm. Lane widths that are greater than the minimum values shown in L&D Vol. 1, Figures 301-2 and 301-4 and, depending on condition, may be candidates for narrowing. Narrower lanes can contribute to lower operating speeds along the roadway, which may be appropriate in dense, walkable corridors or near transit in more rural areas.

Figure 7-8: Lane Narrowing Scenarios


Roadway Before Narrowing
Narrowing General Purpose Lanes to add Separated Bicycle Lanes
Narrowing General Purpose Lanes to Increase Sidewalk and Sidewalk Buffer
Narrowing General Purpose Lanes to Increase Sidewalk Buffer and add Bicycle Lanes

Lane Reduction

Lane reductions, or road diets, are most typically done on roadways with excess capacity where anticipated traffic volumes have not materialized to support the need for additional travel lanes.

The most common road diet configuration involves converting a four-lane undivided road to three lanes: two travel lanes with a turn lane in the center of the roadway, also known as a Two-Way Left Turn Lane (TWLTL)—see L&D Manual Volume 1, Section 402 for more information. The center turn lane often improves safety and reduces motor vehicle delay by giving turning vehicles that previously blocked the through lanes their own turning lane.

The space gained for a center turn lane is often supplemented with painted, textured, or raised center islands. If considered during reconstruction, raised median islands may be incorporated in between intersections (See Section 4.5.3).

Road diets are most appropriate on roadways with the following configurations:

- Four-lane streets with volumes less than 15,000 vehicles/day are generally good candidates for four- to three-lane conversions.
- Four-lane streets with volumes greater than 15,000 vehicles/day may be good candidates for four- to three-lane conversions.
- Six-lane streets with volumes less than 35,000 vehicles/day may be good candidates for six- to five-lane (including a center two-way left turn lane) conversions.

A traffic study should be conducted to evaluate potential reductions in crash frequency and severity, to evaluate motor vehicle capacity and level of service, to evaluate bicycle LOS, and to identify appropriate signalization modifications and lane assignment at intersections before implementing a road diet.

7.6 Driveways and Alleys

See Section 4.5.5 and 4.5.7 for discussions of pedestrian accessibility and motorist speed management at driveways and alleys.

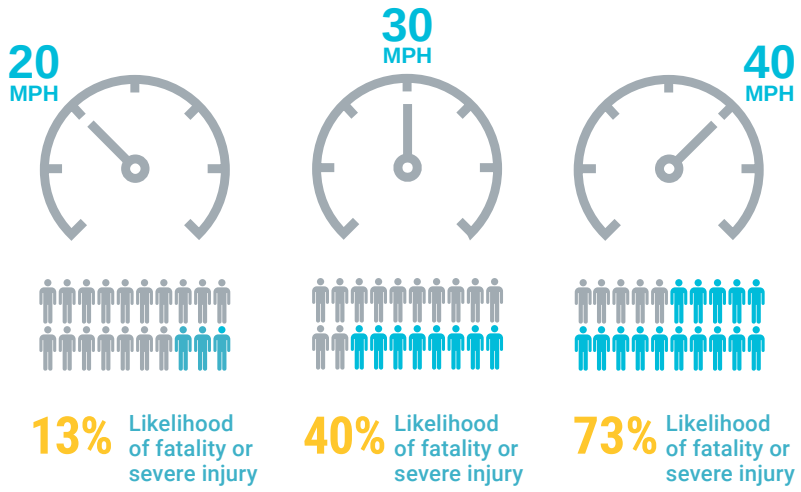
7.7 Crosswalks at Uncontrolled Intersections and Mid-block Locations

See Sections 4.4, 5.6, and 6.5 for discussions of pedestrian and bicyclist design considerations at uncontrolled and mid-block locations.

7.8 Speed and Volume Management for Multimodal Design

People walking and bicycling are particularly vulnerable in the event of a crash, and vehicle speeds where conflicts occur are a primary factor in the likelihood of serious injuries and fatalities (see Figure 7-9). Where vulnerable road users are present and in urban contexts, ODOT's speed zone calculations will be derived from the 50th percentile speed as determined from a speed zone study. For information on conducting a speed zone study, refer to Section 1203 of the TEM.

Figure 7-9: Vehicle Speeds and Risks to Pedestrians[2]



Design speeds are discussed in L&D Manual Volume 1, Section 104. Where pedestrian and bicycle facilities are provided, design speeds should be equal to the legal speed. Using a design speed higher than the legal speed may cause motorists to feel comfortable exceeding the posted speed. When motor vehicle operating speeds create a safety concern for people walking or bicycling, designers should reduce the number of conflict points and overall exposure of pedestrians or bicyclists. Where conflicts remain, designers should increase visibility (e.g., sight distances and illumination) and provide ample warning to both motor vehicles and more vulnerable users. On existing roadways with operating speeds that exceed the legal speed, roadway redesign and traffic calming measures should be considered to reduce speeds and improve safety and comfort for all users.

Traffic calming devices help to manage motor vehicle operating speeds and volumes by introducing changes to the roadway cross-section (horizontal deflection), pavement elevation (vertical deflection), reductions in roadway width, alterations to typical motor vehicle travel patterns, or a combination of these techniques. By managing speeds, reinforcing target design speeds, and managing vehicle volumes, traffic calming increases the comfort of a shared operating environment and minimizes conflicts between users. Traffic calming devices are not appropriate in every context. The following sections discuss both the application and design of traffic calming devices.

The addition of traffic calming treatments can result in through traffic trips diverting to other nearby streets. While this may be preferable for bicycle boulevards (see Section 6.3.2), it may create undesirable conditions on other parallel streets. To avoid unintended behaviors, traffic calming should be considered from a roadway network perspective.

7.8.1. Application

The use of traffic calming devices should consider the following:

- Design speed should target the posted speed.
- Designs should consider both the design and check vehicle.
- Some vertical deflection treatments may have an adverse effect on emergency response vehicles. Many types of vertical deflection can be designed to accommodate transit and emergency vehicles by leaving gaps that match the wheelbase.

Traffic calming treatments are most effective when they are deployed at regular intervals ranging from 200 to 400 ft. between treatments.

7.8.2. Horizontal Deflection

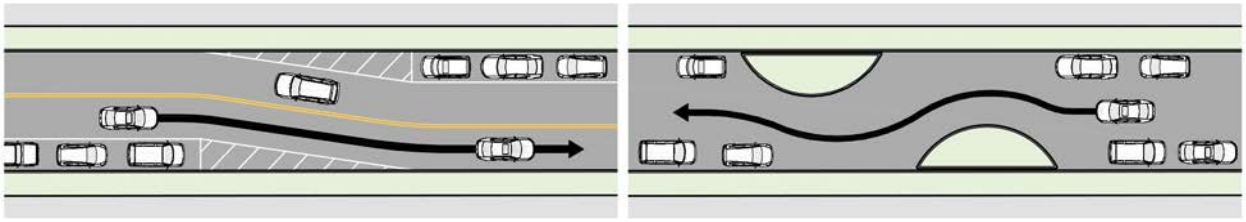
A horizontal deflection hinders the ability of a motorist to drive in a straight line by creating a horizontal shift in the roadway. This shift forces a motorist to slow the vehicle in order to comfortably navigate the measure. Horizontal deflection is most appropriate on local and collector streets. Lateral shifts and mini roundabouts may also be appropriate on thoroughfares. See L&D Manual Volume 1, Section 202, for allowable horizontal deflection and curve design criteria.

Lateral Shifts & Chicanes

Lateral shifts cause travel lanes to shift in one direction, often by shifting on-street parking from one side of a street to the other side of the street. Chicanes are a series of curb extensions, pinch points, parking bays, or landscaping features that alternate from one side of the road to the other to establish a serpentine path of travel for motorists along a street. The following design guidance should be considered for both treatments:

- Lateral shifts and chicanes can be used on two-way streets with one lane in each direction, and one-way streets with no more than two lanes.
- Traffic-calming effects are greatest when deflection shifts vehicles back and forth by at least one full lane width.
- The shifting taper of horizontal deflections should be based on the posted speed. Provide advisory speed plaques (W13-1P) where appropriate to supplement Horizontal Alignment Signs (See OMUTCD, Section 2C.07).

Figure 7-10: Examples of Lateral Shift (left) and Chicane (right)

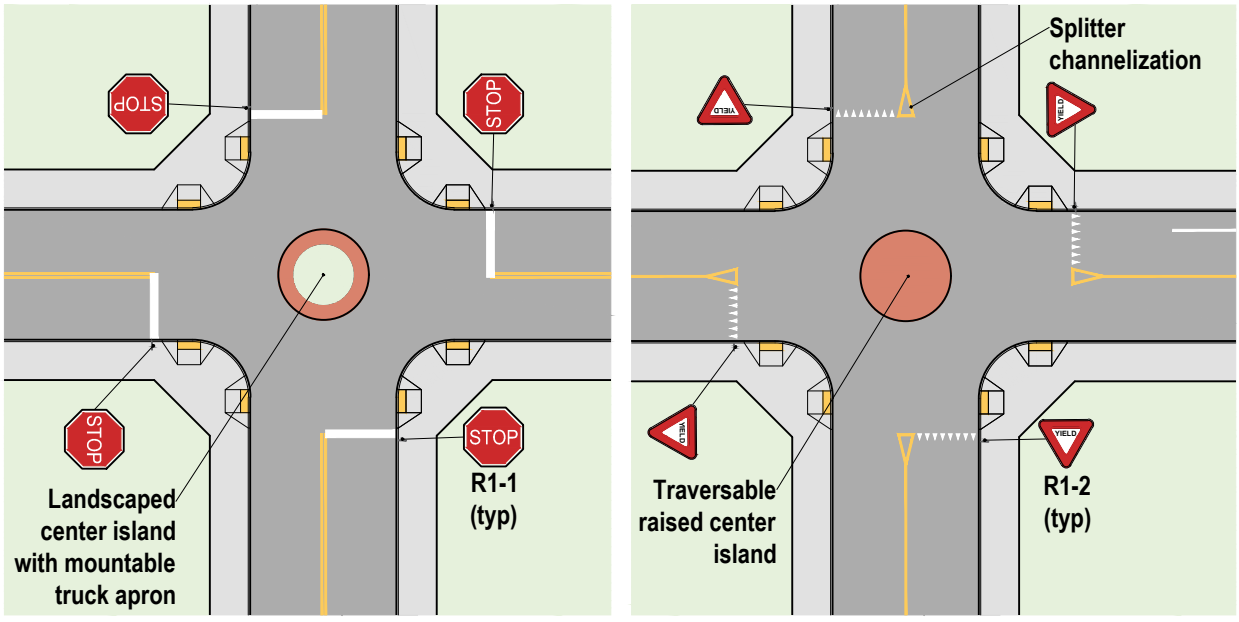


- If vegetation is used within chicanes, it should generally be low maintenance. In locations with mid-block pedestrian crossings, sight distances must be maintained.
- Interim chicanes can be created using a combination of pavement markings, parked cars, flexible delineator posts, or other vertical elements.
- Avoid using these horizontal deflection treatments along streets with bus, freight, or emergency response activity unless traffic volumes are very low and large vehicles can use the full roadway width.
- Bikeways should be maintained throughout to avoid abruptly squeezing bicyclists into motor-vehicle traffic on streets with higher traffic volumes, particularly in locations with uphill grades where bicyclists may be traveling slower than other roadway traffic.

Traffic Circles

Neighborhood traffic circles are primarily used at four-leg, two-lane local streets and are installed to reduce crash severity and slow traffic speeds. Splitter islands are not required on approaches (unlike a modern roundabout), and the central island is typically raised with a mountable apron to prevent a straight-through movement of the typical design vehicle. The occasional control design vehicle should not be precluded from operating within the intersection with encroachment, if necessary, which may include going the "wrong way" to the left of the traffic circle to make a left turn. Landscaping may be planted with the center median if it does not need to be traversable. The local streets typically do not have marked centerlines.

Figure 7-11: Schematic Examples of Mini-Roundabouts and Neighborhood Traffic Circle



Typical Neighborhood Traffic Circle with Stop Control (If Warranted)

Typical Mini-Roundabout

Designers should consider the following:

- The aesthetic value of a traffic circle is an important part of its design. Well-designed traffic circles fit naturally into the neighborhood and can include landscaping, green street elements, or decorative pavement such as stamped concrete, pavers, etc.
- Traffic circles should be visible to street users with pavement marking, signing and reflectors used where appropriate. Regulatory and/or warning signage should be provided to advise traffic to proceed counterclockwise around the circle.
- Careful attention should be paid to the available lane widths and turning radius used with traffic circles to accommodate the design vehicles.
- Maintaining access to underground utilities must be considered.

Mini-Roundabouts and Modern Roundabouts

Mini-roundabouts are primarily used on two-lane collector streets and require all vehicles to yield to traffic in the roundabout and traverse counterclockwise around the circle. Because of their traffic calming effects, they are installed primarily to reduce crashes, but can also reduce delays at minor approaches. Mini-roundabouts share the characteristics of modern roundabouts (See Chapter 9 and L&D Manual Volume 1, Section 403) with approach splitter islands and yield control on each approach. The splitter island may be raised or painted. The central island may be raised with a mountable apron (See Section 7.2.5 and D Manual Volume 1, Section 403.6.4) to constrain the circulating roadway width while still accommodating larger vehicles. Where the diameter of the center circle is less than 8 ft., it may be painted. Mini-roundabouts are typically constructed to fit within existing curb lines at intersections but in some locations may require reconstruction of corner radii to accommodate larger design vehicles. In most cases the addition of new accessible curb ramps will be necessary to accommodate pedestrians at a crossing setback from the circulating roadway. The intersecting streets will typically include marked centerlines.

7.8.3. Vertical Deflection

Vertical deflections, which include speed tables, speed humps, speed cushions, and raised crosswalks, are effective means for controlling the speeds of motor vehicles. OMUTCD Sections 2C-29, 3B.25 and 3B.26 provides guidance on markings and signage for vertical deflection treatments. Vertical deflection as a traffic calming measure is only permitted across local and collector streets where posted speeds are less than 35 mph and where roadway grades do not exceed 8 percent.

In general, all vertical traffic calming devices within roadways should be built with a bicycle friendly vertical deflection profile. The preferred profile is sinusoidal, which is easier for bicyclists to traverse than a circular or flat profile. The use of parabolic profiles should be avoided on streets with bicycle traffic, as their abrupt pavement joint edges can cause discomfort or a loss of control of the bicycle. The front edge or lip of the device should be as smooth as practical and meet the road with minimal vertical. Sinusoidal profiles are also easier for maintenance vehicles to traverse for street sweeping or snow plowing activities, and they have less of an effect on emergency vehicle access.

Speed Humps

Where speed humps are used to control speeds along a roadway, they are most effective when they are placed periodically along the route (every 200 – 400 ft.) to reinforce speed control. These devices should be designed to maintain existing drainage patterns to avoid requiring additional inlets and storm sewer. DWG 7.2 provides additional speed hump design details, which includes tapering the speed hump near the edge of pavement or curbline to minimize retrofit installation costs and allow stormwater to flow into existing gutters. The details also show options for speed humps with gaps between separate humps. These may be desirable on bicycle boulevards, or to better accommodate emergency services vehicles, as they allow the bicyclist or the wider emergency services vehicles to straddle the hump while narrower passenger vehicles cannot avoid them. Designers should consider the existing site conditions and make adjustments where necessary.

Raised Crossings and Speed Tables

A target speed of less than 10 mph for the raised area should be used on roadways with a posted speed of 25 mph, but a target speed of 10 - 20 mph may be used where crossing volumes are low. A target speed of 10 – 20 mph for the raised area should be used on roadways with a posted speed of 30mph.

For both speed tables and raised crosswalk, a 10 foot minimum flat area should be provided. Speed tables are most effective when they are placed periodically along the route (every 200 – 400 ft.) to reinforce speed control.

Raised crossings require additional design considerations (see Section 4.5.5). Raised crossings may also be placed at intersections to reduce both left and right turning vehicular speeds.

7.8.4. Street Width Reduction

Research has shown that motorist speeds can be reduced by creating a sense of enclosure or by creating shared travel spaces that eliminate the perception of motorist priority. This can be accomplished through the provision of continuous or intermittent elements that reduce the effective travel lane width and narrow the field of view, resulting in a naturally slow-speed environment. Designers should consider additional streetscape elements to further enforce to drivers the need to drive slowly and with caution.

Road Diet

A road diet is the conversion of an undivided roadway to a cross-section with fewer or narrower through motor vehicle travel lanes. The elimination or width reduction of travel lanes can reduce the severity of crashing through vehicle speed reduction. It is appropriate for arterial, collector, and local streets in an urban, suburban, or rural setting. The reduction on traveled way widths may also provide space for other improvements such bicycle lanes and crossing islands. See Section 7.5.2 for more design information.

Narrow (Yield) Streets

In many communities, particularly residential neighborhoods, streets are quite narrow. Some of these streets are called "yield streets," "queuing streets," or "woonerfs" because they require motor vehicles to pull to the side, usually into a parking lane or driveway, to allow motor vehicles approaching in the opposite direction to pass. Yield streets are appropriate in residential environments where drivers are expected to travel at low speeds and volumes are low, see Table 7-1.

Table 7-1: Yield Roadway Motorized Traffic Volume and Speed Characteristics

	Average Daily Traffic Volume (ADT)	Operating Speed (mph)
Preferred	500	15
Maximum	2000	25

Yield streets are typically 24–28 ft. wide with parking on both sides, or 21 ft. wide with parking on one side to limit the effective width of the operating space to require motorists to pull into empty parking spaces or driveway openings to allow approaching motorists to pass. Width reduction measures may include on-street parking (See Section 7.2.7), curb extensions (See Section 7.7), median islands (See Section 4.5.3), or a combination of these measures.

For a yield street to function properly, parking density must be relatively high, but motorists must also have regular opportunities to pull to one side. In general, yield streets are most effective where on-street parking utilization falls within 40 to 60 percent of available spaces or when 40 to 60 percent of the curb space is available due to parking restriction and parking demand. When more than 60 percent of the curb is space is regularly available, curb extension or pinch points can be installed to reduce the curb space and create a similar effect. If parking demand is expected to increase, painted curb extensions may be used as an interim measure and removed as parking demand increases.

Yield streets should provide enough room for emergency vehicle access, the occasional moving van or large delivery truck, as well as school buses, trash trucks, and snow plows (when these vehicles are expected), to navigate safely.

One-Lane Pinch-Points

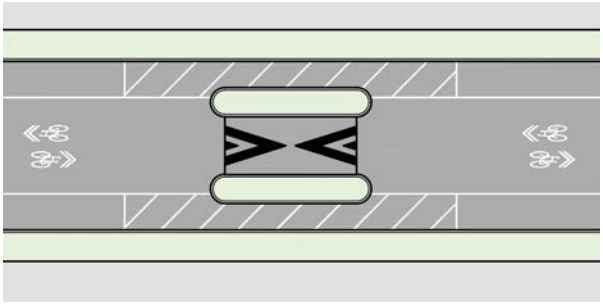
Pinch-points are curb extensions that are constructed to narrow a two-way roadway to one travel lane which requires approaching motorists to yield to each other. This treatment should be reserved for mid-block locations along low-volume local streets. This treatment may be most appropriate on streets with more than 18 ft. of clear operating width which are functioning as two-lane streets, streets with low parking demand, or streets with parking on one side.

Designers should consider the following:

- To function effectively, the width of the opening should not allow two cars to pass: 14 ft. is effective and allows emergency services to navigate the opening.
- The one-lane portion may align with one direction of travel to prioritize that direction or may be centered in the roadway with no directional priority.

- A warning sign (ROAD NARROWS) and YIELD signs (R1-2) may be considered upstream of the pinch point.
- Any vegetation provided in the medians should be low growing and low maintenance.
- Vertical deflection (see Section 7.8.3) may be located within the single-lane section to further reduce speeds. In these instances, a bicycle bypass can be considered to maintain bicyclist speeds (see Figure 7-12).

Figure 7-12: One-Lane Pinch Point Centered in the Roadway with Speed Hump and Bicycle Bypass Lanes



7.8.5. Routing Restriction/Traffic Diversion

Traffic diversion strategies are used to reroute traffic from one roadway onto other adjacent streets by installing design treatments that restrict motorized traffic from passing through. These are often used on Bicycle Boulevards (See Section 6.3.2 and Section 6.5.6) to reduce motorist volumes but can also be used on other roadways where volumes are above desired thresholds for other bikeway types (See Section 7.2) or the expected pedestrian volumes.

The NACTO Urban Street Design and Bikeway Design guides provide additional types of volume management strategies beyond those discussed here.

Regulatory Signage

Signing can be used to prohibit vehicles from entering a roadway using movement prohibition signs (R3-1, R3-2, R3-3, R3-5, R3-27, etc., or DO NOT ENTER signs (R5-1). These prohibitions can be for all hours or could be for peak hours only to optimize flow during times of heavy traffic. Signs should be supplemented with an EXCEPT BICYCLES plaque when bicyclists are permitted to perform the movements that are prohibited for motorists.

Signs may be supplemented by right and/or left turn pavement marking arrows to emphasize the restriction, but pavement markings should not be used when restrictions vary by time of day. Signs and pavement markings alone may not be effective at discouraging motor vehicle access. The following sections depict physical treatments that can be used to supplement signing and markings.

Diverters

A diverter is an island built at an intersection to alter the movement of through and/or turning vehicle traffic. Diverters are commonly designed to maintain through travel for people walking and bicycling while altering routes for motor vehicles.

For all diverters, designers should consider the following:

- Diverter islands are designed to maintain bike and pedestrian access by providing cut-throughs. Standard cut-through width for bicyclists is 6 ft.
- Diverter islands can include a combination of public art or other vertical elements, so long as they keep sight lines clear for bicyclists. Other vertical elements such as signing, flexible

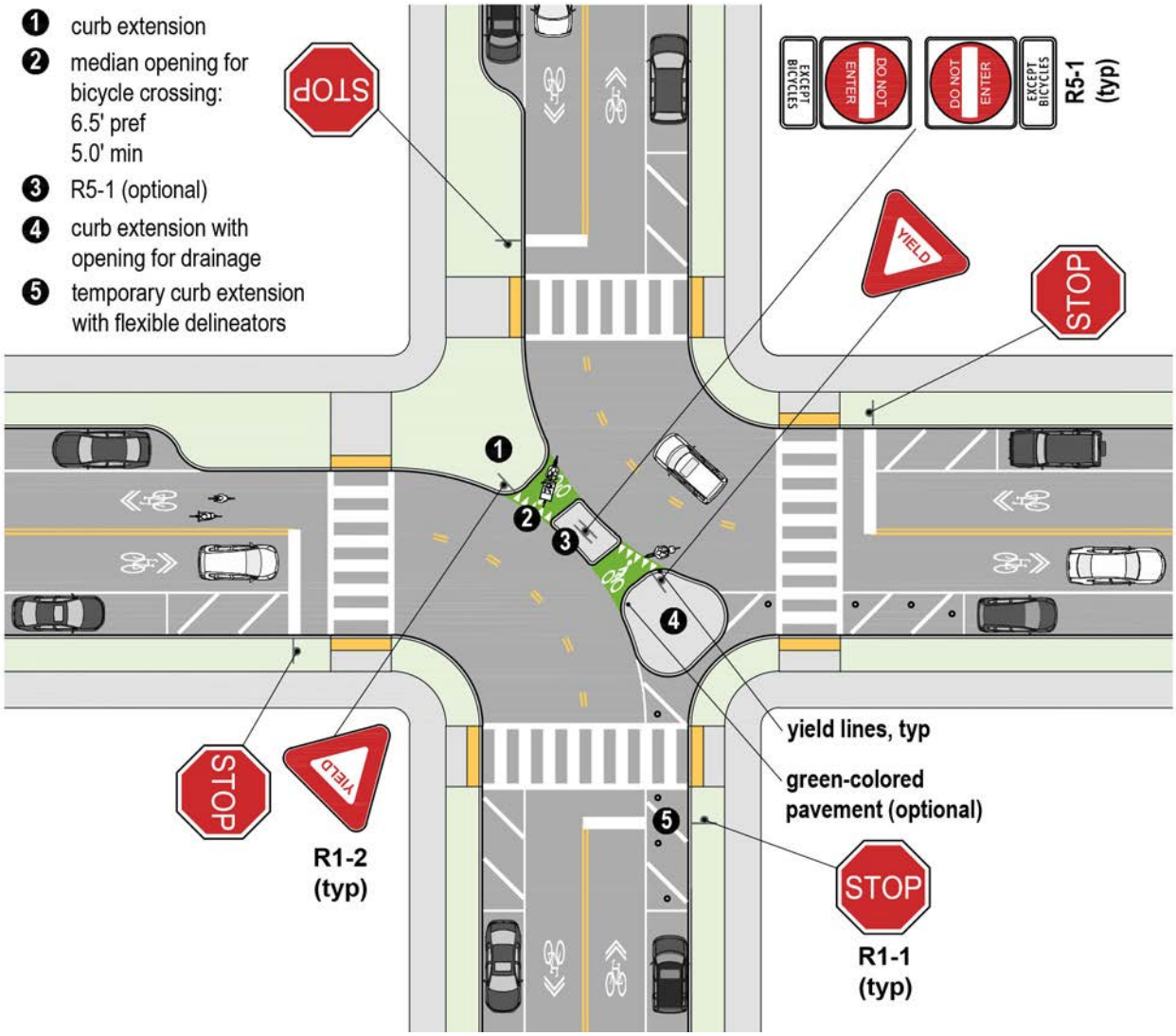
delineator posts, etc. may be appropriate to make the features more visible to motorists and assist snowplow operators when clearing roadways.

- A diverter's effectiveness at limiting speeds is generally limited to the intersection where it is installed. The street may require additional traffic-calming treatments in addition to the intersection treatments to achieve the desired operating characteristics.
- Diverters must be designed with transit and emergency vehicle navigation in mind. In some cases, emergency vehicles must be able to travel over or through the diverter if gaps are spaced to accommodate them or if breakaway gates are used.

Diagonal Diverters

Diagonal diverters (Figure 7-13) are the most common form of full diversion. Diagonal diverters connect diagonal corners creating two disconnected streets. Vehicles are forced to turn, while through travel is maintained for bikes and pedestrians.

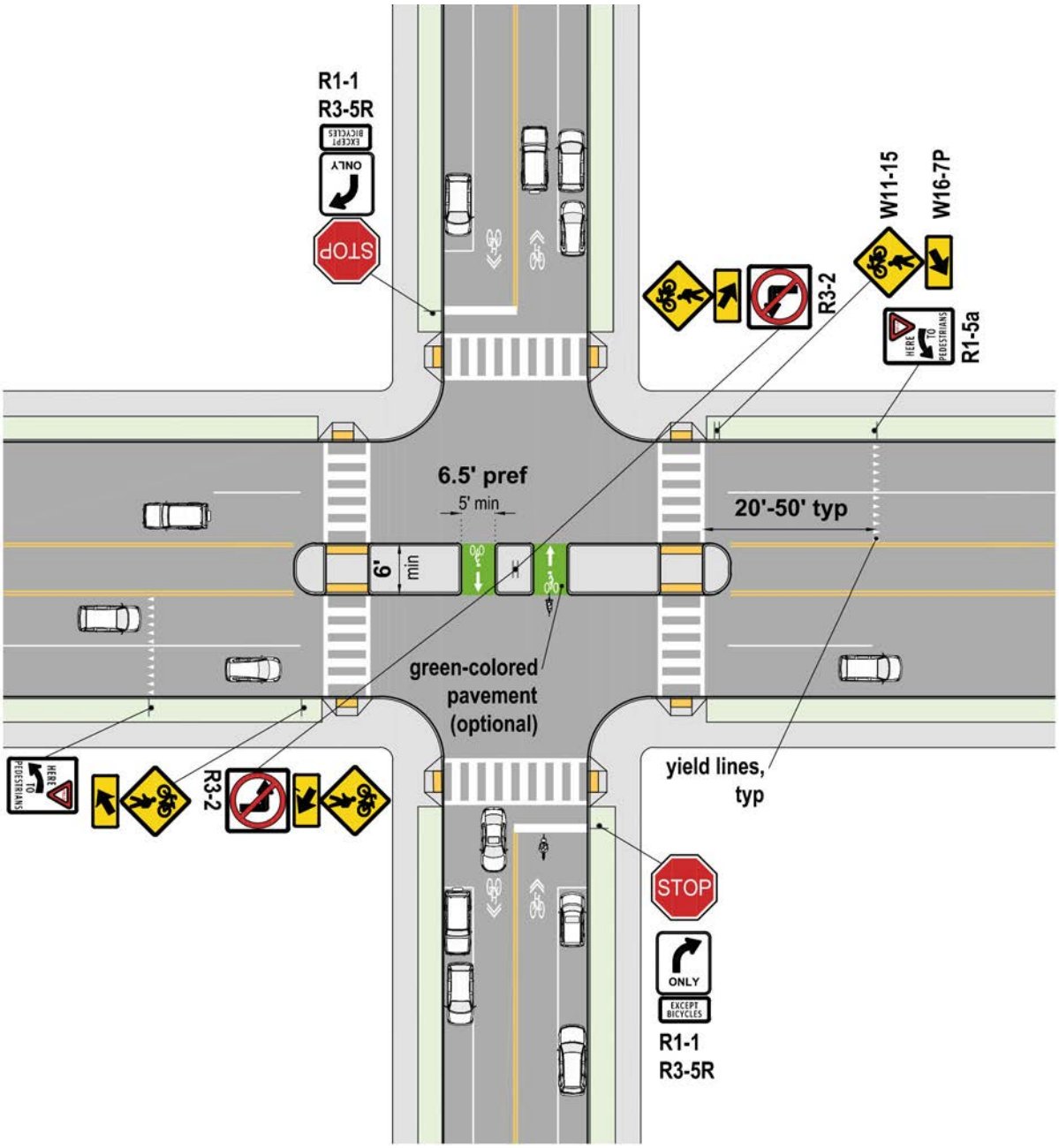
Figure 7-13: Diagonal Diverter



Median Diverters

Median island diverters (Figure 7-14) are a common form of diversion used when minor roadways that include bikeways intersect with major roadways. Median island diverters restrict motorist left turns from the major roadway and restrict the motorist through movement along the minor roadway. They can also provide a crossing island for bicyclists so that the major street crossing can be accomplished as two separate crossings.

Figure 7-14: Median Island Diverter

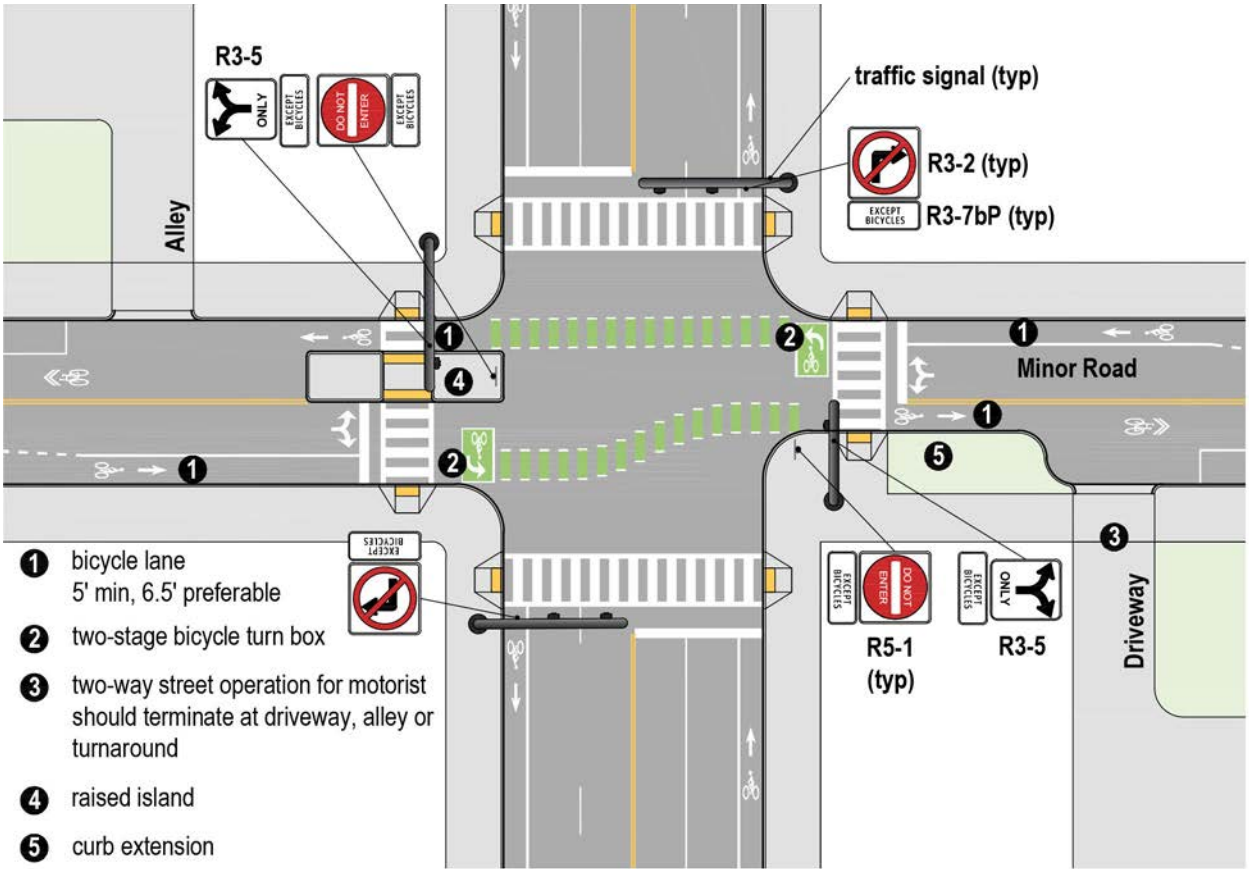


Forced Turn Diverters

A forced turn diverter, or directional closure (Figure 7-15), is a curb extension or vertical barrier extending to approximately the centerline of a roadway, effectively obstructing (prohibiting) one direction of traffic.

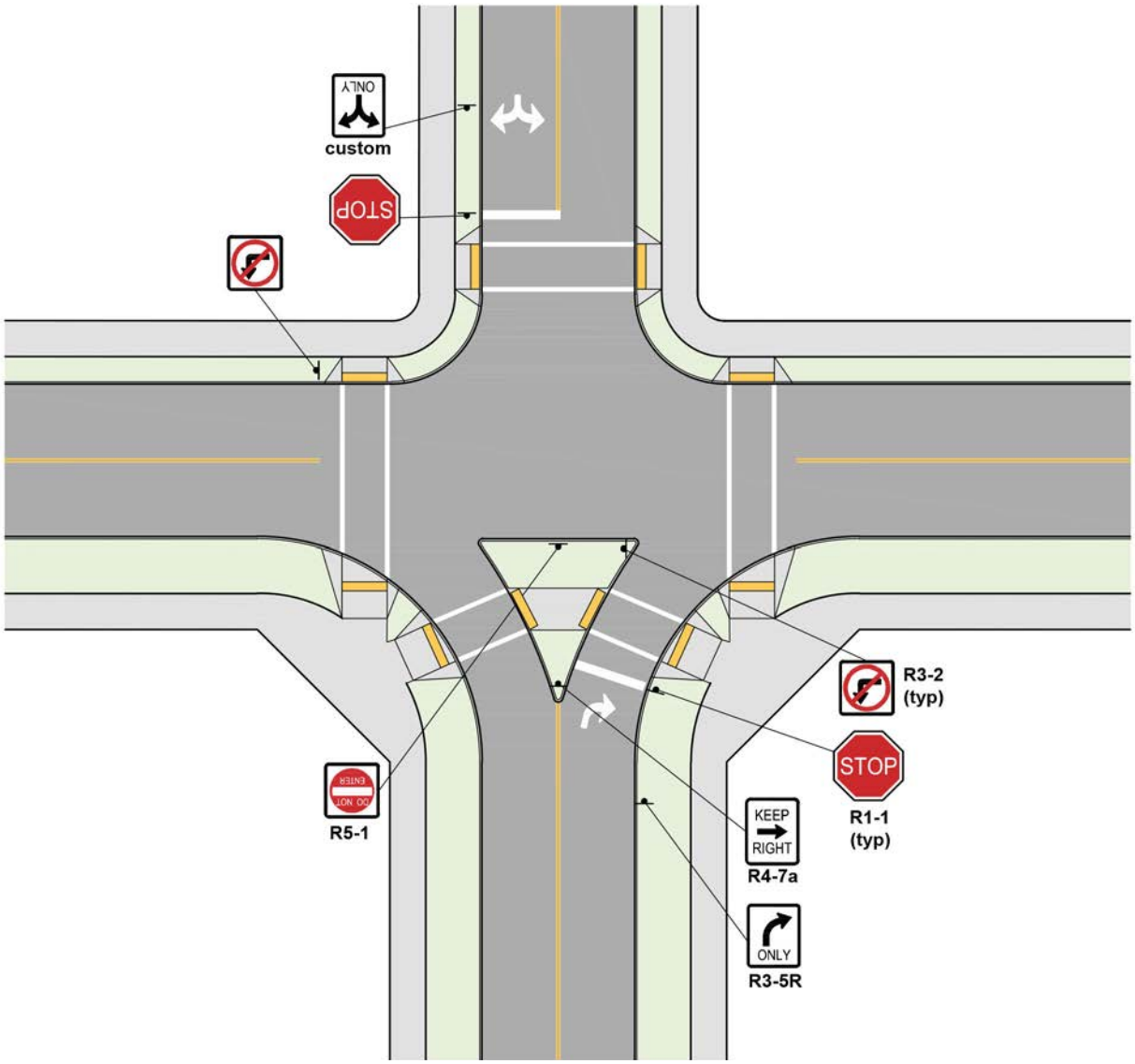
Bicycles are typically permitted to travel through a directional closure in both directions, including the direction in which motor vehicle traffic is obstructed. In some cases, gaps or a contra flow bicycle lane are used to provide bicycle access.

Figure 7-15: Forced Turn - Directional Closure



A second type of forced turn diverter is a right-in/right-out island (Figure 7-16), which prohibits the through and left turn movements. This treatment can be achieved with less infrastructure than the directional closure described above and can better accommodate two-way motor vehicle traffic but may result in higher motor vehicle volumes.

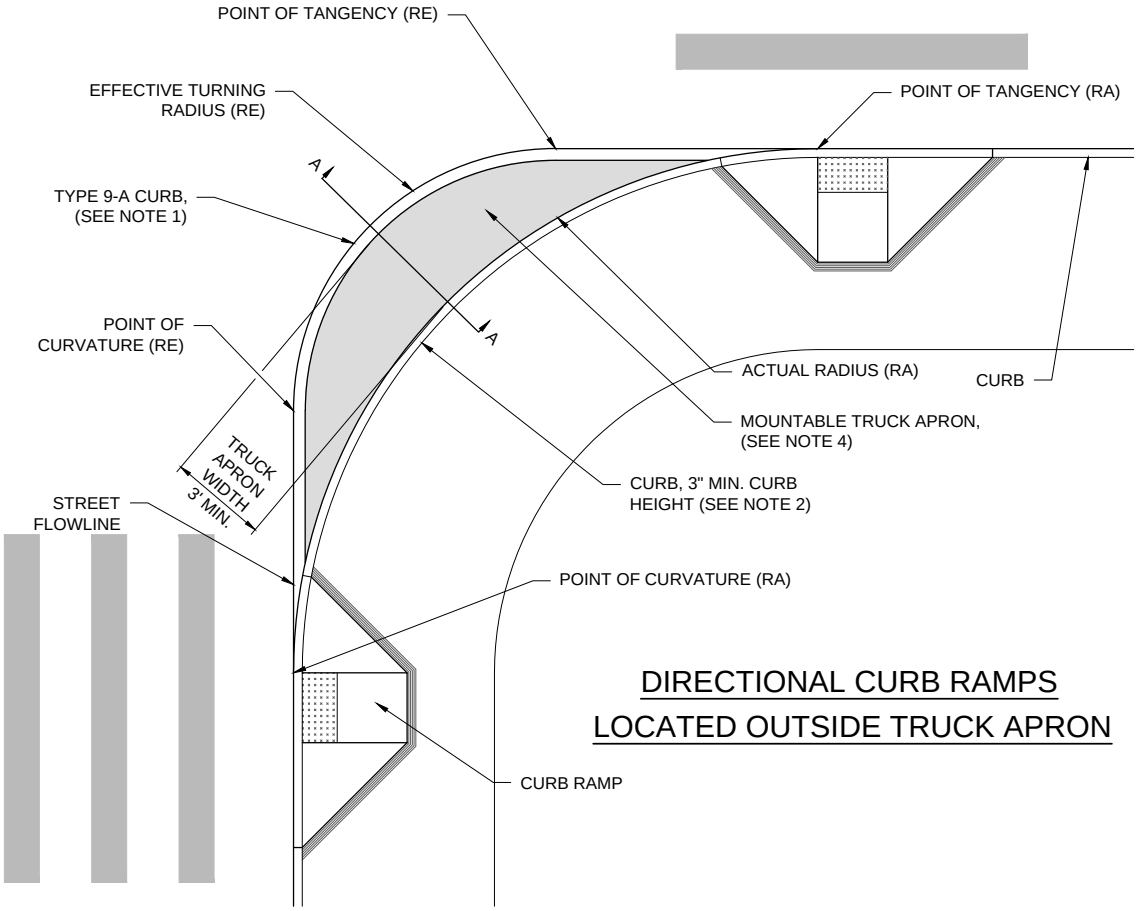
Figure 7-16: Forced Turn - Right-In/Right-Out



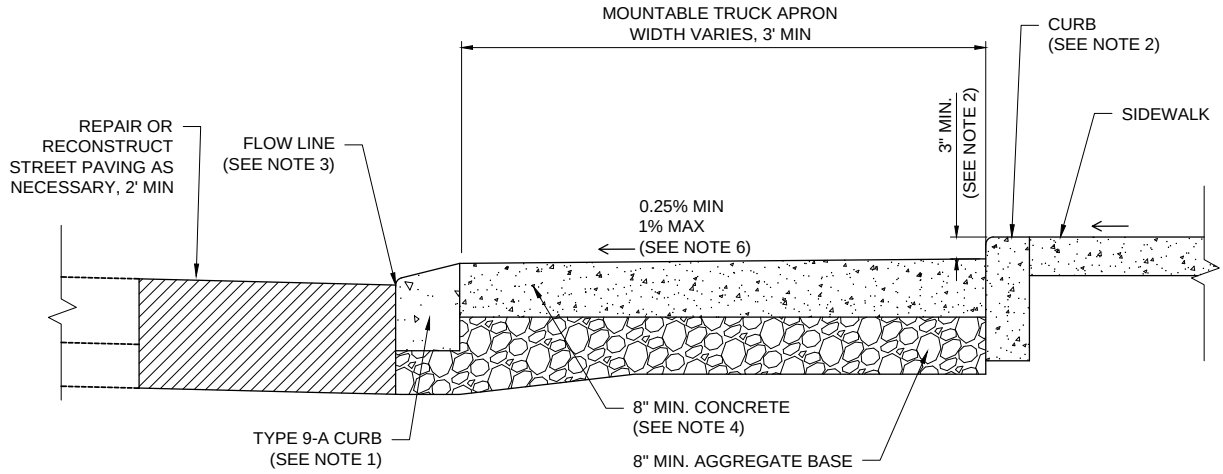
TRUCK APRON DETAILS

DWG 7-1.1

REFERENCE SECTIONS
7.2.5



DIRECTIONAL CURB RAMPS
LOCATED OUTSIDE TRUCK APRON

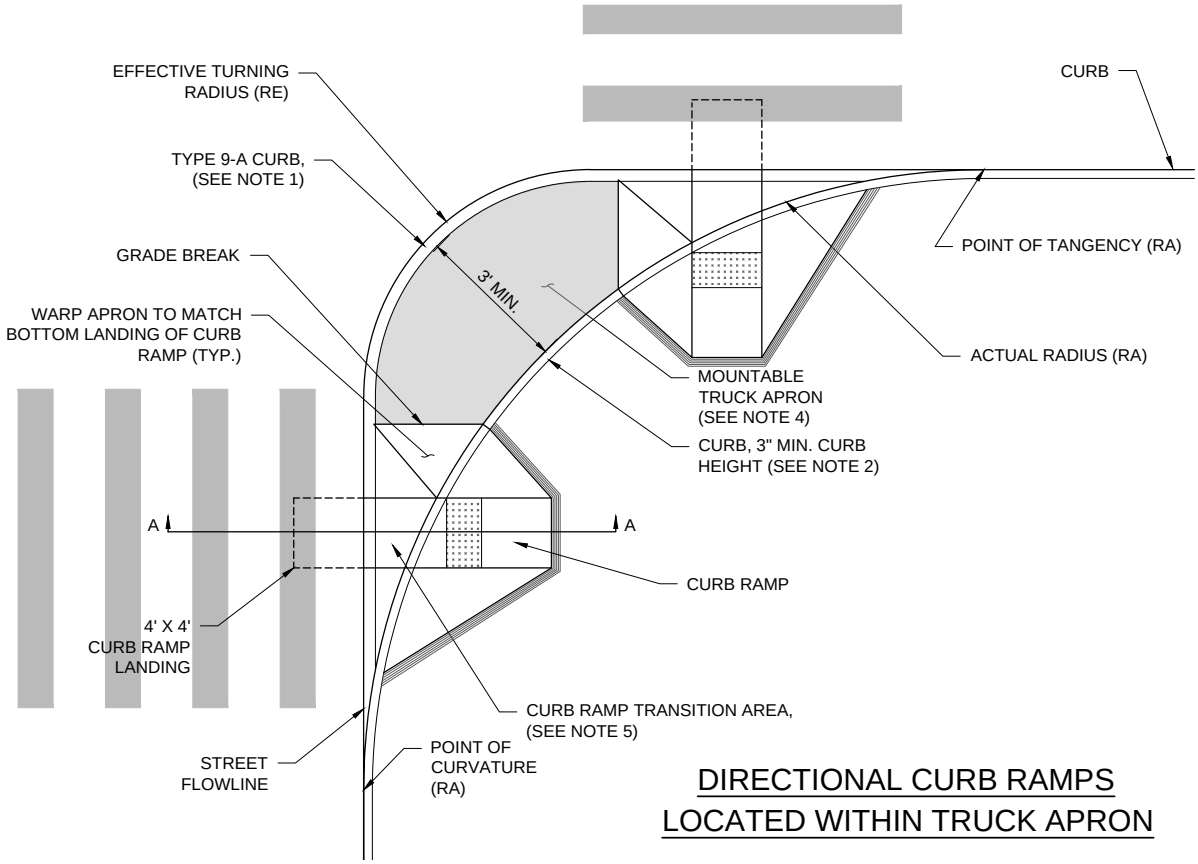

MOUNTABLE TRUCK APRON WIDTH VARIES, 3' MIN
CURB (SEE NOTE 2)
3" MIN. (SEE NOTE 2)
SIDEWALK
REPAIR OR RECONSTRUCT STREET PAVING AS NECESSARY, 2' MIN
FLOW LINE (SEE NOTE 3)
0.25% MIN 1% MAX (SEE NOTE 6)
8" MIN. CONCRETE (SEE NOTE 4)
TYPE 9-A CURB (SEE NOTE 1)
8" MIN. AGGREGATE BASE

SECTION A-A

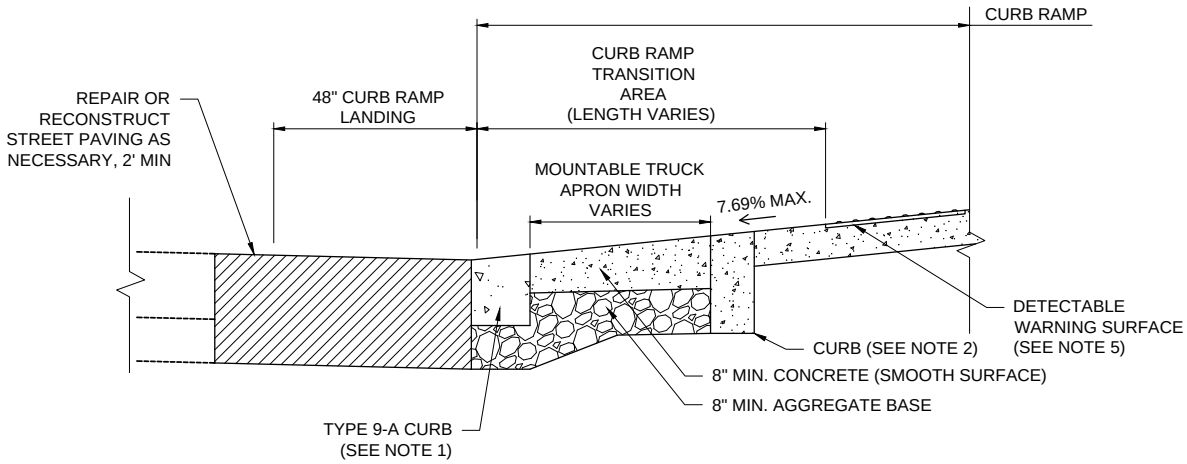
TRUCK APRON DETAILS

DWG 7-1.2

REFERENCE SECTIONS
7.2.5


EFFECTIVE TURNING RADIUS (RE)
CURB
TYPE 9-A CURB, (SEE NOTE 1)
GRADE BREAK
3' MIN.
POINT OF TANGENCY (RA)
WARP APRON TO MATCH BOTTOM LANDING OF CURB RAMP (TYP.)
ACTUAL RADIUS (RA)
MOUNTABLE TRUCK APRON (SEE NOTE 4)
CURB, 3" MIN. CURB HEIGHT (SEE NOTE 2)
A
A
CURB RAMP
4' X 4' CURB RAMP LANDING
CURB RAMP TRANSITION AREA, (SEE NOTE 5)
STREET FLOWLINE
POINT OF CURVATURE (RA)

DIRECTIONAL CURB RAMPS
LOCATED WITHIN TRUCK APRON

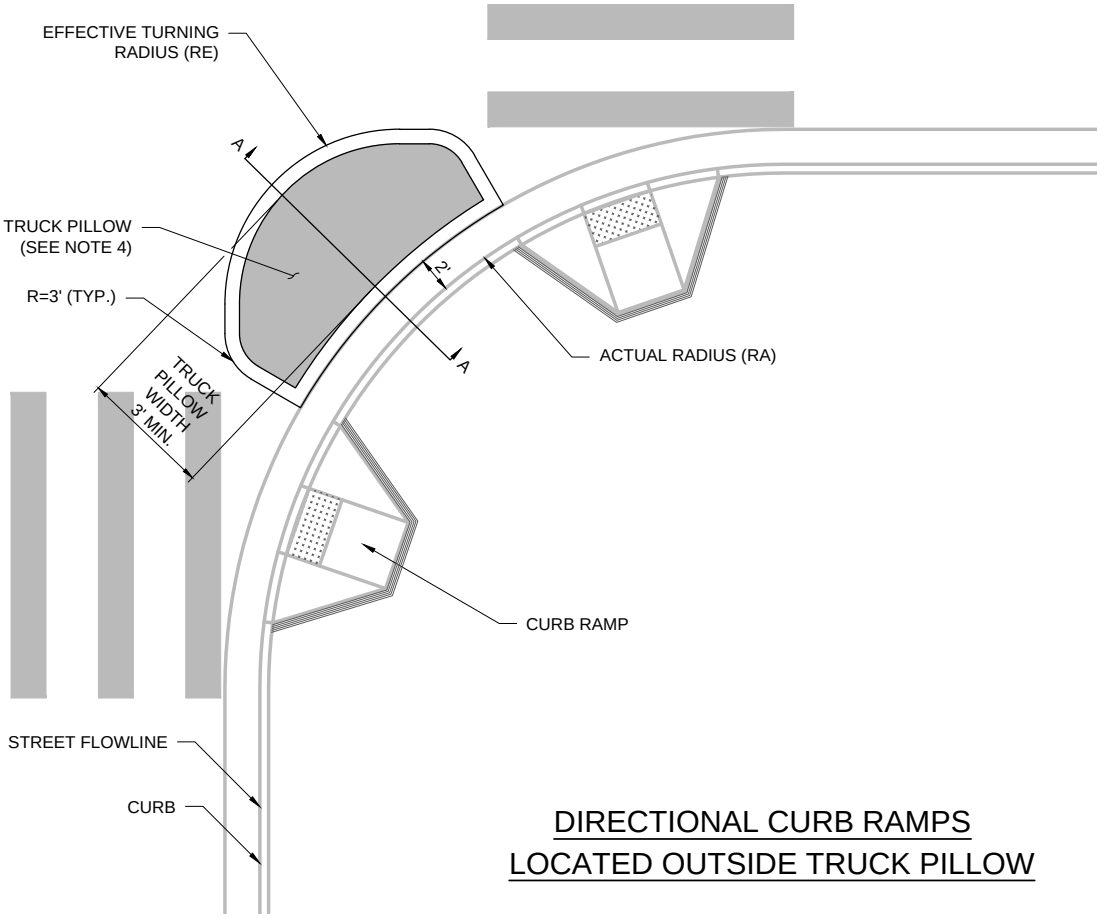

CURB RAMP
CURB RAMP TRANSITION AREA (LENGTH VARIES)
48" CURB RAMP LANDING
REPAIR OR RECONSTRUCT STREET PAVING AS NECESSARY, 2' MIN
MOUNTABLE TRUCK APRON WIDTH VARIES
7.69% MAX.
DETECTABLE WARNING SURFACE (SEE NOTE 5)
CURB (SEE NOTE 2)
8" MIN. CONCRETE (SMOOTH SURFACE)
8" MIN. AGGREGATE BASE
TYPE 9-A CURB (SEE NOTE 1)

SECTION A-A

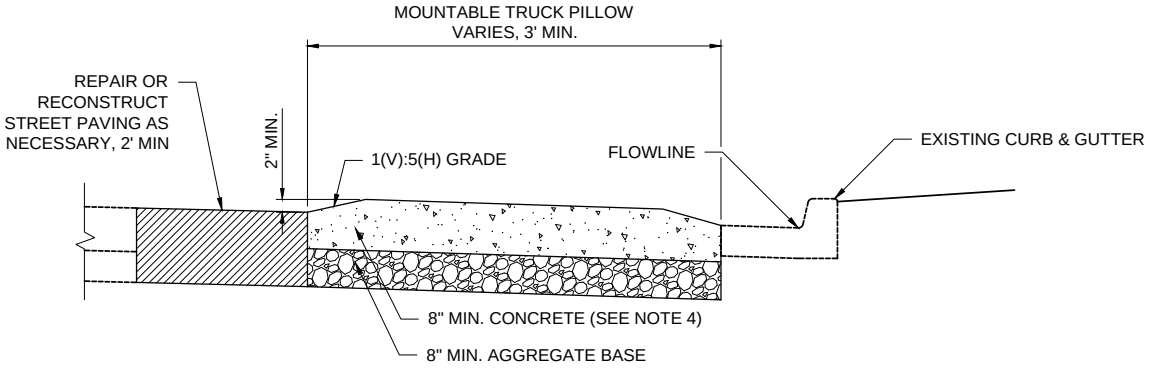
TRUCK APRON DETAILS

DWG 7-1.3

REFERENCE SECTIONS
7.2.5



DIRECTIONAL CURB RAMPS
LOCATED OUTSIDE TRUCK PILLOW



SECTION A-A

TRUCK APRON DETAILS

DWG 7-1.4

REFERENCE SECTIONS
7.2.5

NOTES:

1. TYPE 9 OR 9-A CURB MAY BE USED. THE HEIGHT OF THE MOUNTABLE CURB MAY VARY ALONG THE APRON RADIUS (RE) WITH A MINIMUM HEIGHT OF 1 INCH AND A MAXIMUM HEIGHT OF 3 INCHES. A MINIMUM CURB HEIGHT OF AT LEAST 2 INCHES SHOULD BE PROVIDED AT THE POINT OF CURVATURE IF GRADING PERMITS. CURB HEIGHT MUST BE WARPED TO PROVIDE A 0 INCH CURB REVEAL APPROACHING CURB RAMPS. CURB HEIGHT WILL VARY BASED ON THE WIDTH OF THE APRON, THE CROSS SLOPE OF THE ROADWAY WITHIN THE INTERSECTION, AND THE OPPORTUNITIES TO MAKE GRADING CHANGES BEHIND THE CURB WITHIN THE SIDEWALK AREA.

2. THE HEIGHT OF THE FULL HEIGHT CURB VARIES ALONG THE BACK OF THE APRON (RA) BUT SHALL BE A MINIMUM OF 3 INCHES (6 INCHES PREFERABLE).

3. THE STORMWATER FLOW LINE FOLLOWS THE APRON RADIUS (RE). WHEN THE CROSS SLOPE OF THE ROADWAY WITHIN THE INTERSECTION DOES NOT ALLOW FOR POSITIVE DRAINAGE AROUND THE APRON RADIUS (RE), A TRUCK PILLOW IS REQUIRED.

4. THE MOUNTABLE TRUCK APRON OR PILLOW SHALL BE DISTINCT FROM THE ADJACENT ROADWAY AND SIDEWALK. THE APRON OR PILLOW SHALL BE CONSTRUCTED WITH CONCRETE AND MAY USE INTEGRAL COLOR OR SURFACE TEXTURES OUTSIDE OF THE CURB RAMP AND CROSSWALK AREA. PAVEMENT MARKINGS, RAISED PAVEMENT MARKERS, AND / OR SURFACE APPLIED COLOR MAY BE APPLIED TO ACHIEVE CONSPICUITY.

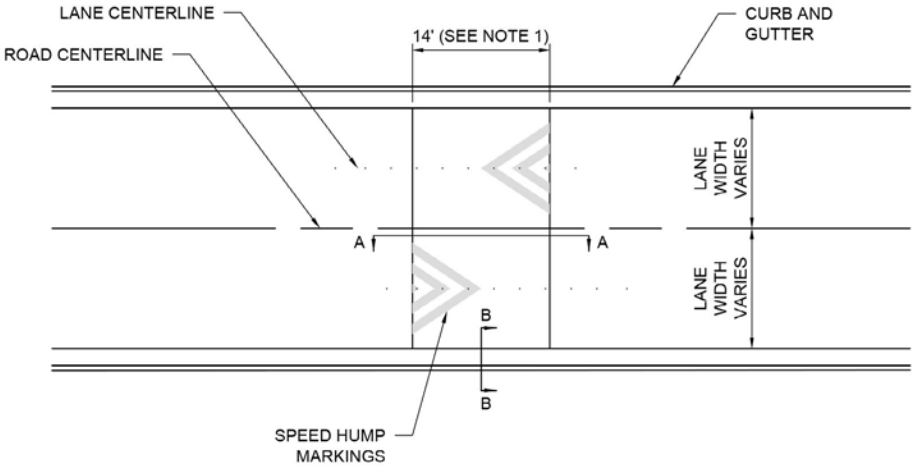
5. THE CURB RAMP TRANSITION AREA TOWARDS THE BOTTOM OF THE CURB RAMP SHALL MEET STANDARD CONSTRUCTION DRAWING BP-7.1 FOR CURB RAMPS. THE LANDING FOR THE CURB RAMPS WILL BE LOCATED BEYOND THE STREET FLOWLINE. IF THE CURB RAMP IS PARTIALLY LOCATED WITHIN THE TRUCK APRON OR PILLOW, THE ACCESSIBLE PATH OF TRAVEL SHALL BE SMOOTH AND THE DETECTABLE WARNING SURFACE SHALL BE PLACED OUTSIDE OF THE TRUCK APRON OR PILLOW AREA.

6. THE TRUCK APRON IS SHOWN SLOPING TOWARDS THE MOUNTABLE CURB. THE TRUCK APRON MAY BE DESIGNED TO INSTEAD SLOPE TOWARDS THE SIDEWALK WITH THE SAME MINIMUM AND MAXIMUM SLOPES IF POSITIVE DRAINAGE CAN BE MAINTAINED AND DISCHARGED BACK TO THE FLOWLINE BEYOND THE TRUCK APRON.

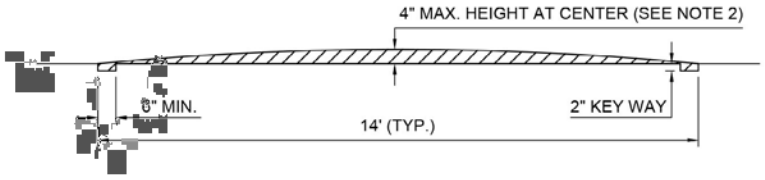
SPEED HUMP DETAILS

DWG 7-2.1

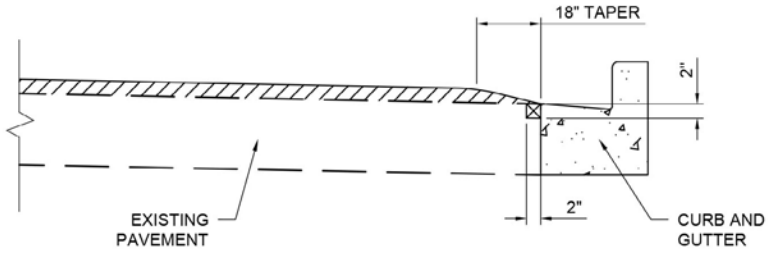
REFERENCE SECTIONS
7.8.3



TYPE A - PLAN VIEW



SECTION A-A

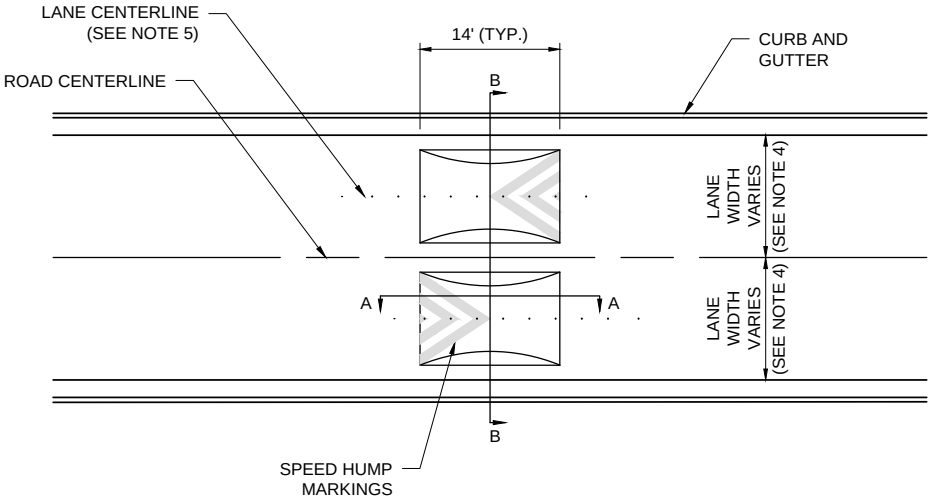


SECTION B-B

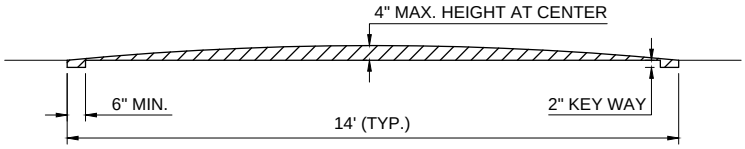
SPEED HUMP DETAILS

DWG 7-2.2

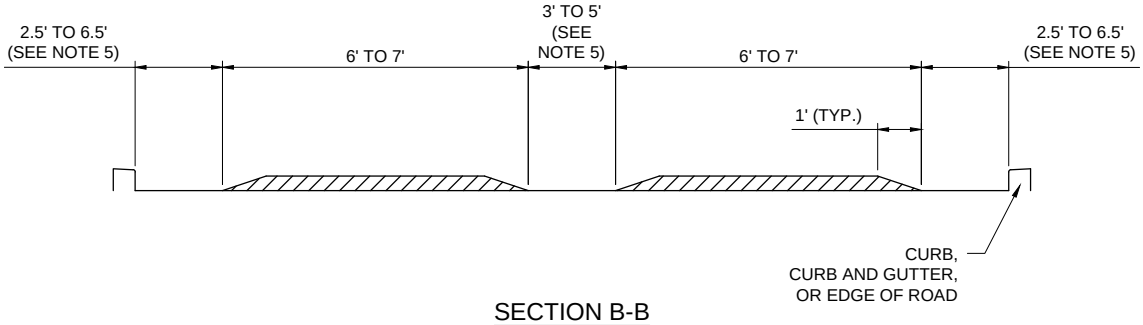
REFERENCE SECTIONS
7.8.3



TYPE B (TWO HUMPS) - PLAN VIEW



SECTION A-A

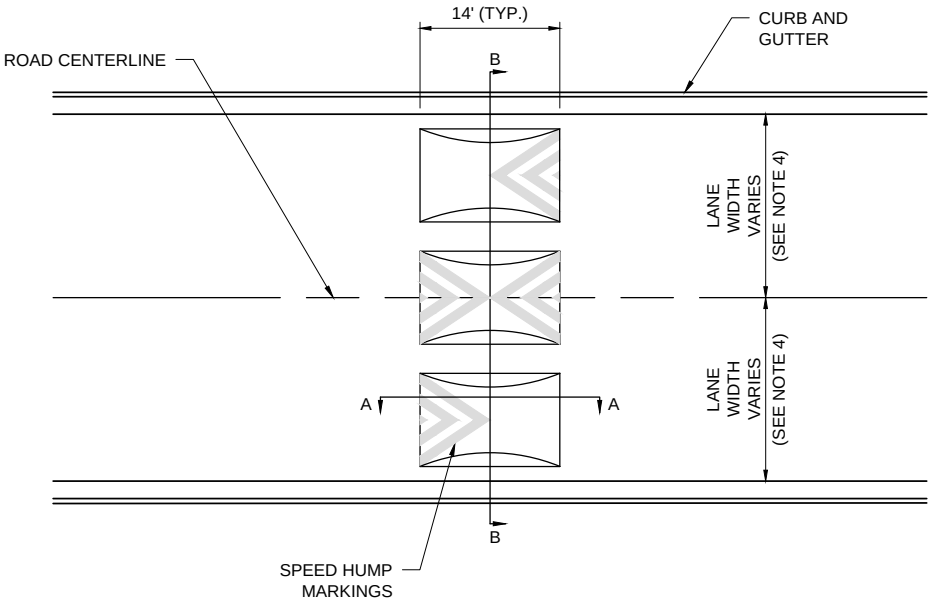


SECTION B-B

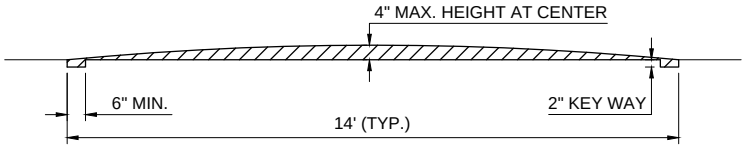
SPEED HUMP DETAILS

DWG 7-2.3

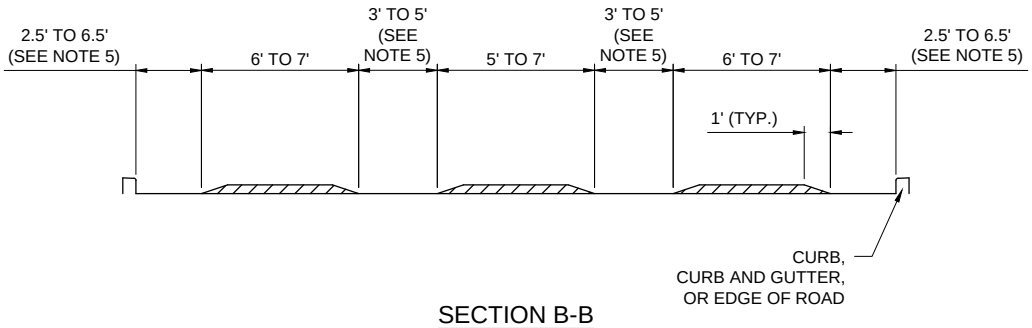
REFERENCE SECTIONS
7.8.3



TYPE B (THREE HUMPS) - PLAN VIEW



SECTION A-A



SECTION B-B

SPEED HUMP DETAILS

DWG 7-2.4

REFERENCE SECTIONS
7.8.3

GENERAL NOTES:

1. TYPICAL LENGTH OF SPEED HUMP IS 14 FEET, BUT CAN VARY FROM 10 TO 14 FEET.
2. TYPICAL HEIGHT OF SPEED HUMP IS 4 INCHES, BUT CAN VARY FROM 3 TO 4 INCHES.
3. LANE CONFIGURATION AND WIDTHS MAY VARY. SPEED HUMPS WILL TYPICALLY BE ARRANGED SYMMETRICALLY, BUT MAY BE ADJUSTED BASED ON SPECIFIC SITE CONDITIONS.
4. SPEED HUMP SHOULD BE CENTERED IN THE TRAVEL LANE. SPACING BETWEEN HUMPS IS VARIABLE TO ACCOUNT FOR SPECIFIC SITE CONDITIONS. WIDTH OF SPACING BETWEEN CURB AND HUMP MAY BE FURTHER INCREASED ON STREETS WITH ON-STREET PARKING IF PARKING IS TYPICALLY OCCUPIED THROUGHOUT THE DAY.

Chapter 7 Endnotes

1 New York City Department of Transportation. Don't Cut Corners: Left Turn Pedestrian and Bicyclist Crash Study. New York City, August 2016.

2 Tefft, B. C. Impact speed and a pedestrian's risk of severe injury or death. Accident Analysis & Prevention. 50. 2013.

CHAPTER 8: SIGNALS, BEACONS, AND SIGNS

Chapter 8: Signals, Beacons, and Signs

8.1 Introduction

Traffic signals manage traffic flow by separating and allocating time to specific movements. They can reduce conflicts between motor vehicles, transit vehicles, bicyclists, and pedestrians. The decision to install a Pedestrian Hybrid Beacon (PHB) or a traffic signal involves a holistic evaluation of numerous factors at the study location and requires the use of engineering judgment to apply and evaluate OMUTCD warrant criteria. Additional details on this process are discussed in Section 8.2.

The design guidance in this chapter covers how to design pedestrian hybrid beacons and traffic signals, including traffic signal heads, signal phasing, signal timing, signing, markings, and pedestrian/bicycle detection. It also includes ways to reduce delay and manage or eliminate conflicts between vulnerable users and motor vehicles. The design guidance provided in this chapter also supplements intersection design guidance provided in other chapters. This design guidance should be used in conjunction with the TEM and the OMUTCD.

8.2 Evaluation of a Traffic Control Signal or Pedestrian Hybrid Beacon

Traffic signals may be installed to facilitate roadway crossings by pedestrians and bicyclists. It may be necessary to consider pedestrian signal or pedestrian hybrid beacon (PHB) installation at crossing locations where one or more of the following conditions occur:

- Where one or more OMUTCD traffic signal warrants or PHB guidelines are met;
- Sight distance is restricted, based on prevailing motor vehicle speeds;
- Motor vehicle approach speeds exceed 30 mph;
- There are four or more through lanes of major street traffic;
- There are insufficient crossing opportunities (including crossings of two through lanes) within about a quarter of a mile from the location in question.

Traffic control signal installation should be limited to locations where less restrictive traffic control devices do not provide adequate crossing opportunities for pedestrians and bicyclists. Even at locations where a traffic control signal is warranted, other treatments such as traffic calming, roundabouts, active beacons, or PHBs should be considered before determining a full traffic signal is appropriate. A traffic signal can increase delays, motorized traffic volumes on minor street approaches, and some types of crashes. PHBs intended specifically for bicycle use can also introduce challenges for bicyclists' timing (see Section 8.6.2).

8.2.1. OMUTCD Traffic Control Signal Warrants

ODOT's TEM (Section 402) and the OMUTCD (Chapter 4C) provide a list of nine traffic control signal warrants to help determine whether a new signal should be installed. Many of the warrants are primarily focused on vehicular traffic flow. There are separate guidelines (not warrants) for PHB installation. Some flexibility is allowed in applying warrants to determine if a traffic control signal or PHB is needed at a bicycle crossing. For example, since bicyclists may operate as vehicles or pedestrians at street crossings, they may be counted as either for a traffic signal or PHB warrant analysis.

Designers have the flexibility to estimate future demand in the absence of a signal or PHB if existing conditions limit vulnerable user crossing opportunities. In some cases, people may not be crossing a street in sufficient numbers to satisfy a warrant because there are not adequate gaps in traffic or they do not feel comfortable doing so – thus they avoid the crossing altogether. For these locations, it may be more appropriate to use an estimated crossing demand for warrant analysis that assumes better crossing protection, as experience shows once a street can be crossed more safely, people will generally cross in greater numbers compared to prior conditions. Designers may consider estimating pedestrian and bicycle volumes as part of developing signal warrant methodology. In these cases, the designer shall coordinate with the appropriate ODOT representative to identify forecasting assumptions.

Projecting volumes is an important consideration where bicycle boulevards and shared use paths are installed and are consistent with the OMUTCD. In these situations, there is an implied understanding that a higher level of care has been taken to ensure bicyclists and pedestrians can safely navigate these routes, as families commonly use such facilities with children. For this reason, agencies and designers should evaluate a proposed facility using the appropriate signal warrants and, if necessary, for a reasonably anticipated volume of peak hour crossings. See Section 2.5 for guidance on projecting pedestrian and bicycle volumes.

The following warrants have the greatest applicability for evaluating the need to install a traffic control signal to assist pedestrians and bicyclists in crossing a street:

- **Warrant 4, Pedestrian Volume** – may be considered at locations where pedestrians experience excessive delay attempting to cross a high-volume street. Bicyclists should be considered with pedestrians in this analysis. The criterion for Warrant 4 (Pedestrian Crossing) may be reduced by 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 ft per second.
- **Warrant 5, School Crossing** – may be considered at locations where there is a desire for school children to cross and there are not adequate gaps for them to do so.
- **Warrant 7, Crash Experience** – may be considered in locations where a threshold of crashes that a traffic control signal could correct has occurred during a 12-month or 3-year period. Thresholds vary depending upon number of approach lanes, type of crash and context (i.e., urban or rural). Ohio has statewide interim approval for alternative signal warrant 7, crash experience data (FHWA IA-19).This warrant may be considered by any jurisdiction within Ohio provided that each abide by the specific conditions for use as contained in the FHWA Interim Approval document and provide ODOT with a list of locations where this warrant was applied.

- **Warrant 8, Roadway Network** – may be considered at locations to encourage concentration and organization of traffic flow on a roadway network. Thresholds are based on existing volumes (that meet one or more of Warrants 1, 2, and 3) and an engineering study that projects five-year traffic volumes. Using this warrant assumes it is part of a major route that either serves as a principal roadway, includes a rural or suburban highway outside or near a city, or appears on an official plan in an urban areas traffic and transportation study.
- **Pedestrian Hybrid Beacon Guidelines** – A PHB may be considered at locations that do not meet traffic control signal warrants or for locations where it might be undesirable to provide a traffic control signal. Guidelines for the PHB are included in the OMUTCD and suggest that PHB's may be appropriate at locations where at least 20 people cross in a peak hour. See the OMUTCD for specific thresholds for speeds, pedestrian volumes, and vehicular volumes. In addition, the TEM (404-5) includes evaluation guidance and how to initiate study components for PHB consideration, including evaluating and documenting all aspects noted in Form 496-16.

According to the OMUTCD (Section 4C.01), with the exception of locations where an engineering study uses Warrant 8 to justify signal installation, a traffic signal installed under projected conditions should have an engineering study performed within one year of energization to determine if it is still justified. If not, the signal should be either taken out of stop-and-go operation or removed.

8.3 Signal Design Guidance for Pedestrian Facilities

Pedestrian signal heads should be provided at all signalized intersections with sidewalks and curb ramps on the approaches and at all signalized intersections where pedestrian activity may be expected or anticipated based on land uses, transit stops, or other factors likely to generate pedestrian activity, regardless of the presence of sidewalks. See ODOT's Signal Design Reference Packet (SDRP) for additional details and references related to pedestrian signal design and installation.

8.3.1. Pedestrian Signals

The OMUTCD (Section 4E.03) defines the conditions under which pedestrian signals shall be provided. At all locations where signals are newly installed, replaced, or significantly modified and pedestrian signals are provided for street crossings, countdown pedestrian displays are required. Pedestrian signals with countdown displays show the number of seconds remaining in the clearance interval and their use has been shown to reduce both pedestrian and vehicular crashes at signals[1].

Accessible pedestrian signals (APS) are devices that communicate information about pedestrian signal timing in nonvisual formats and are integrated with pedestrian pushbuttons. All intersections where pedestrians are expected, regardless of whether the pedestrian phase is automatic or requires actuation, shall be accessible for people with disabilities. This often means that accessible pushbuttons are installed in locations with automatic pedestrian phases. APS installation is

required by PROWAG (R209.1) with any new traffic signal that has pedestrian signals or where there will be significant changes to an existing signal. APS guidelines include the following:

- APS should be placed in consistent locations;
- APS should be located as close as practical to the crosswalk line farthest from the center of the intersection and as close as practical to the curb ramp;
- When installed at signals or PHBs, APS pushbuttons must have both audible and vibrotactile components. Vibrotactile indications integrated into the pushbutton provides information to persons with hearing or visual disabilities;
- APS pushbuttons shall have a locator tone that operates during the DON'T WALK and the FLASHING DON'T WALK intervals only to assist those with low or no vision to find the correct device for a particular crossing;
- APS pushbuttons shall have a tactile arrow that indicates the crossing direction activated by the pushbutton;
- One post and pushbutton assembly should be provided for each crossing. Ideally, pushbuttons on the same corner should be placed a minimum of 10 ft. from each other. This helps clarify which percussive locator tone is applicable to each button for the respective crossing. In constrained areas (e.g., limited building setbacks, unusual geometric conditions), should two APS assemblies be separated by less than 10 ft., an audible walk indication shall include speech pushbutton information and walk messages. These information messages tell pedestrians the name of the street they are crossing. Braille or raised lettering on the pushbutton housing may also provide street name information;
- If an extended pushbutton press feature provides additional crossing time, then an R10-32P plaque shall be mounted adjacent to or integral with the APS pushbutton. For these locations, APS pushbuttons shall be marked with three braille dots forming an equilateral triangle in the center of the pushbutton;
- If the pedestrian clearance time is sufficient only to cross from the curb or shoulder to a median to wait for the next cycle, then an additional APS pushbutton shall be provided in the median.

Some pushbutton housings include a map of the intersection in relief on the side of the housing that informs pedestrians about the number of lanes and islands they will have to cross. These should be provided at wide or complex intersections and when a two-stage crossing may be necessary. However, using a two-stage crossing where pedestrians are required to cross to a median and then to the other side of the street on separate signal phases should be discouraged where sufficient physical protection (e.g., concrete curbing, wide medians) is not included. When installed, two-stage pedestrian crossings should consider a "z"-median where pedestrians are required to traverse a short distance (10 ft. min. preferred) in a center island, facing on-coming traffic, prior to activating a second pushbutton. The center median distance may require adjustments to accommodate site specific conditions.

APS audible messages and tone volumes should be adaptive to the surrounding ambient noise. APS units produce a louder signal message when motor vehicle and other noise at a given intersection is higher. Automatic volume adjustment provides flexibility and allows APS units to adjust so they

are not disturbing to neighbors at night or times of low traffic volume. This is also helpful to visually impaired pedestrians, as the APS does not drown out essential traffic sounds necessary for crossing. See Section 4E.11 of the OMUTCD for volume setting requirements and guidance.

When APS and countdown pedestrian display improvements are made, all crossing associated with the system must be upgraded (see Section 4.3 for ADA requirements, standards, guidelines). Among the requirements provided in Section 4E.04 of the OMUTCD, pedestrian signals should be placed in a conspicuous location, visible to pedestrians waiting to cross. See Section 8.3.1 for additional information on the placement of pedestrian pushbuttons for accessibility.

8.3.2. Pedestrian Detection

Pushbuttons

Where pushbuttons are provided for detection, they shall be accessible. Pushbutton placement must be within easy reach of a pedestrian (and bicyclist when applicable) and obvious to which crosswalk they are associated with.

In addition to standards laid out in Chapter 4E.08 of the OMUTCD, Section 404-2 of the TEM, and Section 8.3.1 of this guide, accessible requirements and best practices are as follows:

- Place pushbuttons so they are adjacent to curb ramp landing or similar surfaces. A level surface with a 1.56 percent cross slope (max.) in each direction shall be provided.
- Pushbuttons may be placed between 1.5 ft. and 6 ft. behind the face of curb or edge of pavement. In some cases, placement as far as 10 ft. is permissible. A distance of 6 ft. is preferable as it allows bicyclists and pedestrians pushing strollers to stop at the button without the front end of their wheel(s) getting closer than 2 ft. from the face of curb or edge of road and provides greater physical separation from moving traffic.
- When placing pushbuttons, consider expected users and their needs. Where bicyclists are expected, a slightly taller pole can provide a surface to hold while waiting for the right of way.

Passive Detection

Passive detection devices are less common, but may be used to actuate or extend pedestrian signals in specific applications. Beacons can be outfitted with motion or break-beam sensors, though care is needed to ensure detection is for only those intending to cross. Infrared crosswalk sensors can detect the presence of slow-moving pedestrians in crosswalks and extend the clearance time.

Passive detection may be used in lieu of or in addition to pedestrian pushbuttons, though careful consideration will be necessary in doing so. Passive detection may be helpful in reducing intersection noise, though pedestrians with vision disabilities may not approach the crossing within the detection zone nor wait at the exact crossing area for activation to occur. They may also not know passive detection is present unless they are familiar with the intersection. In addition, passive detection systems need to be carefully calibrated and monitored to avoid or limit detecting something other than pedestrians.

Passive detection may be an option where compliant pushbutton placement is not feasible at a given intersection. Such factors may include lack of right-of-way, limited building setbacks, or pushbutton placement that would limit or block pedestrian access.

8.3.3. Signal Timing and Reducing Pedestrian Delay

Frequent crossings that accommodate walking speeds for people of all ages and abilities are key to creating a safe, accessible, and connected pedestrian network. Signals are typically timed to prioritize the "major" street movements which may, under certain conditions, increase delay for pedestrians and bicyclists waiting to cross the major street. In addition, when pedestrians and bicyclists are faced with long delays, they may be more likely to ignore signals entirely and cross the road when they perceive an adequate gap in traffic. When this occurs, pedestrians will sometimes choose to cross away from intersections, potentially increasing crash risks. The following section describes best practices for reducing delay and providing accessible crossings to improve safety for all users.

While there are many factors associated with signal timing as it relates to reducing pedestrian delay, corridor consideration should be a factor. Streets in lower density, suburban settings, often do not have comparable pedestrian volumes relative to more dense, urban networks. However, these corridors may have transit operation, which may make road crossing decisions challenging without appropriate crossing opportunities.

Signal Cycle Length

In some instances, where pedestrians routinely experience long delays at signals, they may elect to cross away from the crosswalk at locations where conflicts are not controlled by a signal. Therefore, strategies to reduce overall cycle length can be particularly important for pedestrian safety. Where pedestrians are expected regularly, cycle lengths greater than 60 to 90 seconds should often be discouraged. In addition to reducing cycle lengths, designers may also consider using half-cycle lengths, particularly during off-peak hours. Adaptive signal control, where employed, should have limited variation in cycle length. Operations for adaptive signal control should be confined to suburban settings and event venues where traffic patterns can be highly variable.

Designers should be aware that shortening signal cycle lengths can impact the amount of WALK time that a pedestrian is provided in the pedestrian signal phase (see "Pedestrian Signal Phase Timing", discussed later in this section). While long cycle lengths can increase pedestrian non-compliance, at wider intersections shorter cycle lengths may not be possible without implementing two-stage pedestrian crossings which could increase pedestrian delay compared to providing a longer cycle length. Single stage crossings are preferable in most instances (see Chapter 9 for complex locations where two-stage crossings may be appropriate). Designers can also shorten crossing distances using curb extensions (see Chapter 7), eliminating the need for a longer pedestrian cycle length and potentially reducing the current cycle length.

If a two-stage crossing is provided, designers shall provide a crossing island (see Section 4.5.3) and provide a pushbutton within the crossing island.

Pedestrian Signal Phase Timing

Pedestrian signals provide a WALK phase (steady white walking man symbol) followed by a FLASHING DON'T WALK clearance phase (flashing orange upraised hand symbol with integrated countdown timer). Details for programming the walk and clearance interval is provided in the OMUTCD (Section 4E.06) and the TEM (Section 404). Pedestrian signal timing shall meet the following requirements:

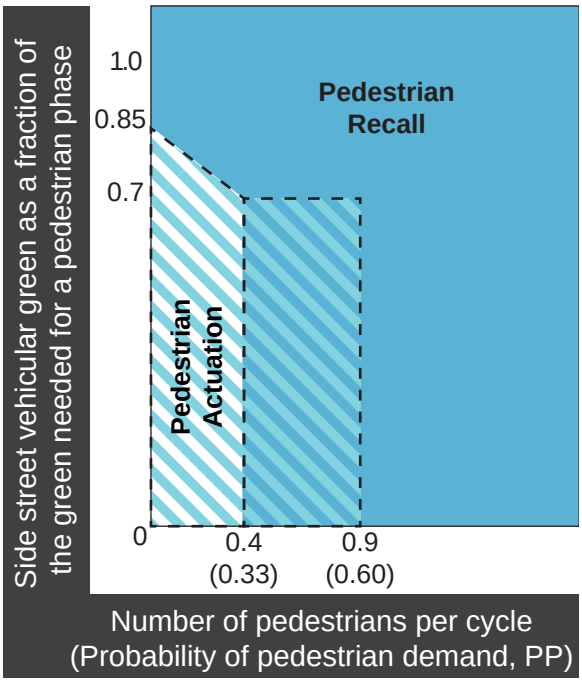
- The duration of the WALK indication should allow sufficient time for a pedestrian to react to the signal and enter the crosswalk. The OMUTCD recommends a minimum walk interval of seven seconds, though it allows for a walk interval as low as four seconds in certain situations;
- A clearance interval based on a maximum walking speed of 3.5 ft. per second from the face of curb or edge of shoulder to the point where they have cleared the farthest lane in the crosswalk;
  - » Where a crossing has a higher proportion of slow-moving pedestrians, slower walking speeds of 3.0 ft. per second or lower may be programmed. A longer clearance interval can also be requested by pedestrians using a longer push on the pushbutton.
  - » Passive detection may also be considered, provided that the system can sense slower pedestrians and extend the clearance time.
- The total WALK + FLASHING DON'T WALK phase (walk plus clearance interval) shall be long enough to allow a person with a walk speed of 3.5 ft./sec. to walk from the pushbutton to the point where they have cleared the farthest lane in the crosswalk. When a pushbutton is not present, the crossing distance should be 6 ft. wider than the width of the road;
- In addition to the recommendations and guidance in the OMUTCD, designers should consider a longer walk interval (e.g., sufficient for a pedestrian to react and walk to the center of the intersection) at locations where there are more than two travel lanes to be crossed or roadway posted speeds are higher than 30 mph.

Signal timing should strive to maximize the WALK + FLASHING DON'T WALK phase such that the total pedestrian time is equal to the total concurrent vehicle green and yellow timing (see Figure 8-1). Providing a shorter WALK phase is sometimes proposed to split the green phase between the pedestrian crossing and turning vehicles. This application is discouraged as it is an informal treatment that does not clearly convey the phasing intention; pedestrians may elect to cross anyway after observing that the concurrent through movement is still green. To address conflicts, designers should instead use one or a combination of treatments listed in Section 8.3.4.

Figure 8-1: Maximizing the WALK Interval

ODOT's typical practice is to terminate the FLASHING DON'T WALK phase at the same time as the concurrent vehicular green indication. However, the OMUTCD (Section 4E.06) allows this interval to overlap with the concurrent vehicular yellow phase. See the OMUTCD (Section 4E.06) for further details.

Figure 8-2: Recall versus Actuated Pedestrian Phase for Coordinated-Actuated Arterials



Pedestrian Recall and Actuation

Pedestrians should not always be required to push a button to call the pedestrian phase at locations with high pedestrian volumes. This is particularly important in downtown corridors or business districts where there tends to be significant pedestrian volume and relatively short cycle lengths. In such environments, fixed time operation with time-of-day phase plans often functions more efficiently compared to actuated or semi-actuated signal timing. Fixed time operation allows for signal controllers to call pedestrian phases each cycle. In a fixed time grid, pedestrian WALK + FLASHING DON'T WALK intervals are often the maximizing factor for phase length, as the time necessary to accommodate pedestrian movements exceeds the time needed for motor vehicles. Designers should follow the guidance in Figure 8-2 for providing pedestrian recall or actuation[2]. This could be accomplished based on different signal timing plans at certain times of day or day of the week.

Signal timing plans, when updated, shall provide a sufficient walk phase for all crossings. If it is determined that the pedestrian phase should switch from actuated to recall based on the time of day, designers can minimize confusion by ensuring the pushbutton includes a confirmation light. When the signal operations have switched to pedestrian recall, the detection indicator can be programmed to illuminate by default.

8.3.4. Signal Phasing for Managing or Reducing Conflicts

There are a variety of alternative signal phasing options for reducing or eliminating conflicts between motorist and pedestrians. Designers should consider both the operational and safety impacts of signal phasing changes at an intersection. Designers should also be aware that a phasing scenario may necessitate a separate motor vehicle turn lane and an additional signal phase, which may increase delay for some users, including pedestrians. Fully separated crossings may require longer cycle lengths, which may result in reduced user compliance with signal indications and increased potential for conflict. The following sections describe four major phasing scenarios, criteria, and considerations. Often, there may not be one solution, but a combination of treatments for specific periods or scenarios to address pedestrian safety.

8.3.4.1 Leading Pedestrian Intervals (LPIs)

Leading Pedestrian Intervals (LPIs) or Leading Through Intervals (LTIs) may be used to give pedestrians a head start (typically a minimum of three seconds) when crossing the street. LPIs are a proven safety countermeasure to reduce vehicle-pedestrian crashes at intersections. Implementation allows waiting pedestrians to enter the crosswalk where they become more visible to conflicting motorists. Both LPIs and LTIs accomplish the same goal through different strategies:

- Leading Pedestrian Intervals - With traditional signal phasing, parallel pedestrian WALK and motor-vehicle circular green indications start at the same time, immediately after the conclusion of the red clearance interval. With LPIs, the walk phase begins as usual and parallel motor vehicle circular green indications start after a brief period. Designers should provide APS units where LPI's are provided; without APS units, pedestrians with low or no vision may not be able to maximize the advantage of LPIs, as they otherwise use the noise of concurrent vehicles to determine when to begin walking.
- Delayed Turn or Leading Through Intervals -A delayed left (or right) turn or LTI provides a green signal to through movements while delaying permissive left (or right) turns for a specific period. This delay time may vary based on site specific conditions, but (similar to an LPI) is usually between three and six seconds. This option minimizes intersection capacity impacts while providing a partially protected pedestrian phase, allowing those on foot a head start in order to establish themselves in the intersection before turning movements are allowed after the protected left (or right) turn phase.

When curb extensions or a protected intersection is provided, pedestrians can establish themselves in the crossing before vehicles due to the distance between the stop line and the edge of the curb where a pedestrian would wait.

Table 8-1 provides the equation for calculating the LPI interval (rounded to the nearest second) found in ODOT's Signal Design Reference Packet (SDRP).

Table 8-1: Formula for Leading Pedestrian Interval (LPI)

Leading Pedestrian Interval (LPI) Formula
$LPI\ (sec.) = \frac{(W_1 + W_2)}{S_w}$
Where:
LPI = Leading pedestrian interval (sec.)
W_1 = Width of first lane of moving vehicles (ft.)
W_2 = Width of shoulder, bike lane, and/or parking lane (ft.)
S_w = Walking speed (typically 3.5 ft./sec.)

An approach meeting any one of the following criteria may be a good candidate for the installation of an LPI:

- Reported crash history finds one or more crashes per year have occurred over the last three years between vehicles turning on green and pedestrians crossing the street on the associated crosswalk with the pedestrian WALK signal;
- A visibility issue exists between the driver's view of pedestrians on the crosswalk due to obstructions or poor sight distance at an intersection approach that can be improved through an LPI. LPIs by themselves don't resolve sight distance limitations, as they don't protect pedestrians who arrive at the end of the WALK phase. Physical measures to remove corner sight obstructions should be given primary consideration;
- Intersection observations reveal conflicts between crossing pedestrians and turning vehicles in which there is a risk of collision should their movements and speeds remain unchanged;
- One of the two movement volumes (turning vehicle volume (A), or pedestrian volume (B), identified below) meet at least one of the thresholds identified in Table 8-2 for a given warrant.

When a protected left turn phase is provided, it should occur as a lag to prevent left turning vehicles from continuing to cross during the LPI. Designers must avoid the "yellow trap" (see TEM Section 403-9) when providing a lagging turn phase.

Table 8-2: LPI Volume Warrant Thresholds

Warrant	Turning Vehicles Volume (A)	Pedestrian Volume (B)
Vehicle Peak Hour	≥130 per hour	≥25 per hour
Pedestrian Peak Hour	≥100 per hour	≥50 per hour
4-Hour Vehicular and Ped Volume	≥105 per hour	≥30 per hour
8-Hour Vehicular and Ped Volume	≥100 per hour	≥25 per hour
School Crossing	≥50 per hour	

8.3.4.2 Protected Pedestrian Phase and Turn Restrictions

Protected pedestrian phases or protected-only signal phasing for turn movements can significantly reduce conflicts between pedestrians and motorists. This process involves eliminating specific motor vehicle phases (e.g., left turns) that cross concurrent pedestrian phases. For example, if the permissive left turns (either green ball or flashing yellow arrow) that cross pedestrian WALK/ FLASHING DON'T WALK phases is eliminated, there is no longer a turning conflict for the crossing

during that phase. In these cases, pedestrian phases may occur before (lead) or after (lag) conflicting vehicular movements.

Turn restrictions or protected pedestrian phases may be considered when one or more of the following criteria are met:

- There are high conflicting turning vehicles volumes. High turning volumes are defined as equal to or exceeding:
  - 200 total right and left turning vehicles per hour;
  - 50 left turning vehicles per hour when crossing one lane of through traffic; or
  - 100 right turning vehicles per hour.
- There is a high volume of total approaching traffic (greater than 2000 vehicles per hour for all approaches);
- There are high pedestrian volumes (pedestrians are 30 percent of vehicle volumes or 300 pedestrians per hour);
- Crash patterns at the study location or nearby locations with similar geometry support the use of separating motor vehicle and pedestrian phasing. Typically, this encompasses three or more left-turn or right-turn collisions where pedestrians had the right of way over a three-year period;
- The available sight distance is less than the minimum stopping sight distance criteria listed in the L&D Manual Volume 1;
- The intersection geometry is unusual (streets intersect at acute/obtuse angles or streets have significant curvature approaching the intersection), which may result in unexpected conflicts and/or visibility issues;
- An intersection in close proximity to senior housing, elementary schools, recreational areas, playgrounds, and/or health facilities.

Protected pedestrian phases or protected-only turn phases may be implemented on a permanent basis, during specific hours, or "on-demand" when a pedestrian is present and activates the pushbutton. If only one movement or street meets the criteria above, consider a treatment to address those specific issues before implementing an intersection-wide approach (i.e., provide protected-only turns for the major roadway and allow for permissive turns on the minor roadway, if turning volumes are low on the minor roadway).

Turn Restrictions

Permissive left turns may be prohibited on demand through programming a signal controller to display a red left arrow when a conflicting pedestrian movement is called. Such programming may require staff time on the part of the jurisdiction where the signal is located in order to maintain signal flexibility and coordination.

A NO TURN ON RED (R10-11) sign may be used to prohibit right turn movements at all times, or a dynamic NO TURN ON RED sign may be installed to limit turns at specific times or conditions. Motorists turning right on red tend to focus on finding a gap in cross traffic. Driver attention in

these situations tends to be on conflicting traffic approaching from their left, and not necessarily a pedestrian beginning to cross from the driver's right. Drivers may also encroach into the crosswalk while waiting for a gap in traffic, effectively blocking the crosswalk. Right turn on red restrictions may be used to reduce these conflicts, though such signs may not be effective if sight distance is not limited by geometry or other roadway features (landscaping, business signs, etc.) without significant enforcement efforts. Where left turns on red are legal on one-way streets, such restrictions may be appropriate for similar reasons.

Right turn on red restrictions increase the number of turns on green, which tend to be higher speed maneuvers, particularly at intersections with larger curb radii. Consequently, such restrictions may not always improve pedestrian safety and shouldn't be used as a default treatment without an engineering study.

8.3.4.3 Concurrent Pedestrian Phase with Permissive Vehicle Turns

At most signals, the WALK indication for pedestrians is displayed concurrent with the green indication for parallel through vehicular movements. Concurrent timing often allows vehicles to turn left or right across the crosswalk during the WALK and FLASHING DON'T WALK phases with change interval countdown indication (pedestrian clearance interval), provided the motorists yield to pedestrians. To mitigate conflicts and improve motorist yielding, designers may consider the following treatments:

- Regulatory signs, such as the R10-15a series "TURNING VEHICLES YIELD TO [PEDESTRIANS]" (see Section 8.8.1);
- Flashing Yellow Arrows (see below);
- Geometric treatments to reduce vehicle speeds and increase sight distances such as raised pedestrian crossings and curb extensions (see Chapters 3, 4, and 7).

Flashing Yellow Arrows

Flashing yellow arrows (FYAs) may be used for left or right turning motor vehicles to emphasis that drivers may proceed after yielding to oncoming traffic and/or pedestrians in a crosswalk. FYAs allow flexibility in providing permissive turns while warning drivers of potential conflicts. For all ODOT roadways, designers shall follow standards in both the TEM, Section 403-7and OMUTCD, Section 4D.18.

8.3.4.4 Exclusive Pedestrian Phases

An Exclusive Pedestrian Phase (EPP), sometimes referred to as a "Barnes Dance", stops vehicular traffic in all directions, allowing pedestrians to cross the intersection in all directions, including diagonally. This treatment can produce a safer operation over conventional phasing but delay for both pedestrians and motorists can be higher than conventional signal timing.[3] Most often, a protected pedestrian phase, specific turn restrictions, or LPIs are more appropriate solutions. An EPP may be preferred over a protected pedestrian crossing for the following scenarios:

- A combination of the criteria listed in Section 8.3.4.2 is met and 15 percent of pedestrians desire to cross diagonally;

- During special events that occupy a substantial portion of the public right-of-way (e.g., street fairs, parades);
- The start and end of school days for major school crossings;
- Intersections where certain motor vehicle turning movements are either not permitted or not in conflict with designated pedestrian crossings.

Signs may be attached to signal poles or pedestrian pushbuttons to inform people that the intersection has an EPP and they may cross diagonally; to inform where an EPP must be actuated by a person waiting to cross; or to deter crossing against the pedestrian signal concurrently with vehicle traffic. Signals that include EPP should time pedestrian phases to accommodate the longest possible crossing.

If a diagonal crossing is employed, designers may need to consider how a person with a visual disability would know that they could cross diagonally. Such determinations need to be carefully considered along with pushbutton placement and pedestrian ramp design for accessibility. Pavement markings should be designed in accordance with the OMUTCD (Figure 3B-20).

8.4 Signal Design Guidance for Bicycle Facilities

This section's design guidance covers traffic signal head options for controlling bicycles, signal phasing, signal timing, and detection. The decision to install a traffic signal or pedestrian hybrid beacon (PHB) involves a holistic evaluation of numerous factors at the study location and requires an evaluation of OMUTCD warrant criteria in addition to the use of engineering judgment. Additional details on this process can be found in Section 8.2. The design guidance provided in this chapter supplements intersection design guidance provided in other chapters.

8.4.1. Indication Options

A vehicular signal head controls a bicyclist traveling in a shared lane or adjacent bicycle lane. Where it is necessary or desirable to control a bicycle separately from a motor vehicle, a bicycle may be controlled by a traffic signal designated for bicycle use only, or by a pedestrian signal head. Traffic signal indications for a bicyclist along a corridor should be as uniform as possible.

Standard Traffic Signal Face for Motor Vehicles and Bicycles

Standard signal control is appropriate to control both motor vehicles and bicyclists riding for both shared lanes and adjacent bicycle lanes. Supplemental signage may be appropriate to instruct bicyclists to follow motor vehicle signal control in cases where applicability is ambiguous.

Pedestrian Signal Heads

Using pedestrian signals to control bicyclist movements is generally discouraged except on shared use paths, but may also be appropriate for:

- separated bikeways traveling in the same direction as the closest motor vehicle travel lane and the pedestrian signal is well oriented for bicyclists to see,
- locations where an LPI is provided and allowing bicyclists to follow the pedestrian signal means they are provided a protected time to cross without turning vehicles, and
- projects with insufficient funding to provide separate bicycle signals, such a quick-build (rapid implementation) projects or those implemented as part of a resurfacing project where signal work is not part of the project scope.

Where a bicycle is required to follow the pedestrian signal, a "[BICYCLE] USE PED SIGNL" (R9-5) sign shall be posted and the pedestrian signal must be readily visible and discernable to bicyclists. Where a bicycle may follow the pedestrian signal but can also follow the standard traffic signal (such as locations where the LPI provides a protected phase), a "BICYCLE MAY USE PED SIGNAL" sign should be considered.

Where bicyclists are required to follow a pedestrian signal, they are only legally allowed to enter the crosswalk during the WALK phase. Research has found low bicyclist compliance rates at locations where bicyclists are directed to follow pedestrian signals.[4] Most bicyclists continue to enter crosswalks on the FLASHING DON'T WALK phase, as it is timed for a pedestrian who moves much more slowly than a bicyclist. Additionally, at locations where the WALK indication is only four to seven seconds, bicyclists who comply with the signal are likely to experience more delay than bicyclists who enter during the FLASHING DON'T WALK phase. Caution should be exercised when requiring bicyclist to use pedestrian signals, particularly at locations with long crossings or unique signal timing.

Standard Traffic Signals Designated for Bicycle Use Only

A separate standard traffic signal may provide a separate signal exclusively for bicyclist use. When used, a "[BICYCLE] SIGNAL" (R10-10b) sign shall be installed immediately adjacent to the signal. A bicycle signal is typically used in the following situations:

- Where the bikeway is a one-way or two-way separated bike lane;
- Where bicyclists' position in the bikeway does not allow them to see motor vehicle or pedestrian signals that may otherwise be able to control their movement, and;
- Where intersection complexity is such that signals may be helpful, as determined by engineering judgment.

Bicycle Signal Faces without Concurrent Vehicle Turns (Interim Approval)

Bicycle signals may use a [BICYCLE] symbol face when used in compliance with FHWA's Interim Approval (IA)-16. Ohio has statewide interim approval for the use of bicycle signal faces. This is an optional treatment that may be used by any jurisdiction within Ohio provided that each abide by the specific conditions for use as contained in the FHWA Interim Approval document and provide ODOT with a list of locations where the treatment has been installed. There are many benefits to using bicycle signal faces and research indicates that bicycle signals increase compliance with the traffic control and reduce bicycle crashes.

Under IA-16, [BICYCLE] faces may only be used where "bicycles moving on a green or yellow signal indication in a bicycle [symbol] signal face are not in conflict with any simultaneous motor vehicle movement at the signalized location, including right (or left) turns on red." The Interim Approval also prohibits the use of bicycle signal faces at pedestrian hybrid beacons. Situations where bicyclists follow pedestrian signals or where a standard traffic signal head is designated for bicycle use are not restricted by the provisions of the Interim Approval for bicycle signal faces.

8.4.2. Bicyclist Detection

At locations with active warning devices, pedestrian hybrid beacons, or traffic signals, there are various techniques that can be used to actively or passively detect bicyclists. Semi- or fully-actuated signals should passively detect bicycles for phases with "no recall" (i.e., to call the signal and extend the side street green) or "min recall" (i.e., to extend the green on the main street). If a signalized intersection approach cannot accommodate passive detection, a curb-side pushbutton for active detection should be provided. The designer should also reference TEM, Section 402-5.1 for detection technology considerations, design, and placement.

Detection Technology

Passive detection equipment does not always reliably detect bicyclists. Bicycle detector installations should be tested under a variety of lighting and weather scenarios to confirm effectiveness. Below is a list of detectors commonly used to detect bicyclists at traffic signals as well as considerations for each type:

- Radar Detection System – It is ODOT's preference that radar detection be used at state-owned and maintained intersections, see TEM, Section 420.5. Some radar detection can distinguish between user types. Detection systems that are not able to do so should be either replaced or supplemented if signal operations require a distinction between bicyclists and motor vehicles.
- Inductive Loop Detection - Quadrupole inductive loops, Type Q and Type D, are two options for loop detector configurations for bicycles. Powerhead loops provide better bicycle detection at stop lines while quadrupole loops are typically used for dilemma zones to extend green phases. They can be used to detect bicycles on shared use paths and bike lanes, as well as in travel lanes on roadways.

  - » Type Q loops can best detect bicyclists when they are above the loop wire.
  - » Type D loops have a magnetic field everywhere within the loop and thus are better for detecting bicycles within the entire loop area. Type D is also particularly effective at rejecting vehicles in the adjacent travel lane, allowing the use of a higher sensitivity setting on the detector amplifier.
- Video Detection System - Video detectors may have challenges detecting vehicles, including bicycles, due to poor streetlighting. Video detection can also be problematic when the sun is low in the sky, which can cause glare and potentially skip phases. This may also be the case during inclement weather (e.g., heavy rain, fog, or snow), though it can be somewhat mitigated by ensuring detection zones are appropriately illuminated.
- Infrared Detection – Bicyclists can be detected through fog, snow, and other environmental constraints that impair video detection.

Bicycle pushbuttons may be used to supplement passive detection. Pushbuttons may also be used where it is desirable for a bicyclist to be detected, but not a motorist (e.g., a bicycle boulevard crossing an arterial with a pedestrian hybrid beacon or a Toucan crossing). Where used, pushbuttons should be reachable by bicyclists and be accompanied by explanatory signage.

Location

Passive bicycle detection should:

- be located in the expected path of bicyclists;
- extend across most of the bicycle lane or shared roadway lane width;
- be adjacent to a curb or other type of footrest, when present.

Detection should also be included in bicycle boxes and two-stage turn queue boxes. In bicycle boxes, detection should be provided both in front of general purpose lanes and bicycle lanes. In two-stage turn queue boxes, the detection zone should include the full area of the marked queue box. Both bicycle boxes and two-stage turn queue boxes have Interim Approval from FHWA (see Section 6.5.1).

When used, bicycle pushbuttons should be placed within a reasonable reach from a bike lane or shared use path. They should allow bicyclists to actuate them without dismounting while satisfying lateral offset requirements from the AASHTO Roadside Design Guide. This can be accomplished by placing bicycle pushbuttons a maximum of 18” from the face of curb, which is an exception to the bikeway shy distance recommendations provided in Section 3.6.2. If there are concerns about a motor vehicle striking the pushbutton pole, bollards may be installed to protect the equipment with the understanding that this could be a hazard to turning motor vehicles. Alternatively, bike ramps should be provided so that a bicyclist can access a sidewalk or separated bike lane to actuate a pushbutton.

Pushbuttons intended both for pedestrians and bicyclists should be located and operated in accordance with accessibility guidelines. Section 8.3.2 provides guidance on the location of pushbuttons when they are on a sidewalk or shared use path. Where bicycle pushbuttons are installed, they do not have to meet accessibility guidelines or OMUTCD requirements for placement.

In locations where pedestrians and bicyclists have parallel crossings and pushbuttons are used to activate a warning device or other active traffic control device, pushbuttons for pedestrians and bicyclists may be placed on the same pole or separate poles. While there is a recommended minimum spacing of 10 ft. between two pedestrian pushbuttons on the same intersection corner, separate pushbuttons for bicyclists and pedestrians do not have a minimum separation recommendation. Pushbutton placement 6 ft. behind the curb is preferable to allow bicyclists and pedestrians pushing strollers to stop at the pushbutton without the front end of their wheel(s) getting closer than 2 ft. from the face of curb or edge of road.

Signs and Markings

When installed, a bicycle detection marking should indicate to bicyclists where they should position themselves to be detected. OMUTCD Section 9C.05 includes bicycle detector pavement markings that can be used. The pavement marking can also be supplemented with a BICYCLE SIGNAL actuation sign (R10-22). This marking and sign can be used with any type of bicycle detection.

8.4.3. Signal Design Considerations

The OMUTCD establishes requirements for the size, arrangement, number, visibility, and positioning of vehicle traffic signals at an intersection. Bicycle signal locations are guided by similar principles and IA-16. The following guidance is intended to supplement the OMUTCD. In general, designers should minimize the number of mast arms and/or pedestal poles by combining equipment where possible. This minimizes the number of fixed objects that can be damaged or cause injury and reduces clutter.

Size and Layout of Displays

All signal indications in a bicycle signal face shall be the same size, including those that display arrows and those that display bicycle symbols. The primary bicycle signal head for the bicycle movement shall use an 8 inch or 12 inch diameter lenses. When the primary bicycle signal face is located on the far-side, a 12 inch diameter bicycle signal shall be used if it is located more than 120 ft. from the stop line.

Bicycle signal faces with 4 inch diameter lenses may only be used as a supplemental, near-side signal. Near-side bicycle signal faces may alternatively be 8 inches in diameter. The smaller size allows it to be mounted at a lower height, improving visibility to approaching bicyclists.

Number of Displays

The OMUTCD and SDRP prescribe the use of two signal faces for a primary motor vehicle movement. As bicycles are rarely the primary movement, the use of one bicycle signal face is generally sufficient. A supplemental near-side signal should be considered in the following situations:

- Locations with protected bicycle phases, as bicycle crash risk is increased if the bicycle signal fails;

- Per IA-16, if the signal head is located more than 80 ft. beyond the bicycle stop line (a supplemental near-side signal head shall be provided when the signal head is more than 120 ft. from the bicycle stop line);
- Intersections that require diagonal or unusual bicycle movement through the intersection.

An additional benefit of a second bicycle signal display is that it provides an added safety feature in case one of the displays malfunctions.

Visibility

At least one signal face should be visible a minimum of 120 ft. before the stop line based on stopping sight distance for a bicycle traveling 15 mph on a flat grade. This distance should be increased where higher bicycle speeds are expected, such as on downhill grades (see Section 3.2.1). Where bicyclists do not have a continuous view of the signal for the minimum sight distance, a W3-3 sign "SIGNAL AHEAD" should be installed.

Bicycle signals should be installed such that visibility is maximized for bicyclists and minimized for adjacent, conflicting motor vehicle movements. Visibility-limiting lenses may be appropriate so long as bicyclists can still see the indication, though such equipment may not effectively shield adjacent travel lanes. As such, other methods to distinguish bicycle signals may be necessary. These may include lower or pole mounted placement, use of smaller signal heads than those controlling motor vehicle traffic (e.g., 8 inch vs. 12 inch), and/or different color signal backplates (ODOT standard signal backplates are black with a 2 inch reflective strip along the perimeter) and/or equipment housing. Legend use or supplemental word messages on backplates is prohibited.

Where existing vehicle traffic signal heads are anticipated to be the sole source of guidance for bicyclists, designers shall check that they are located within the cone of vision measured from the bicycle stop line, as described in the OMUTCD. If bicyclists are required to follow optically programmed or shielded vehicle signals, the signals shall be visible to approaching bicyclists. If the vehicle signal faces fall outside the cone of vision, supplementary vehicular or bicycle signals should be provided.

Placement

The primary bicycle signal head should be mounted in a lateral position that reduces the potential for pedestrians, landscaping, or other signal equipment to block the view of the signal for approaching bicyclists. The recommended distance from the edge of the bikeway is 5 ft. or less. If possible, mounting bicycle signal heads overhead is preferred. If bicycle heads are side-mounted, they should be installed on the same side (i.e., left or right) of the bikeway along an entire corridor.

The spacing between bicycle signal heads and motor vehicle signal heads should be maximized. Bicycle signal heads should not be placed between two motor vehicle signal heads with the same signal face as another motor vehicle signal head. Bicycle signal heads should have a minimum separation of 3 ft., either vertically or horizontally, from other signal heads to reduce the potential for confusion. However, bicycle signal head placement on existing traffic poles may make it difficult to meet the OMUTCD lateral signal separation requirement. Where bike signals and traffic

signals are located in close proximity, it may be desirable to consider one or more of the following strategies to reduce potential for confusion:

- Provide optical programming or shielding on both signal faces;
- Mount the bike signal face at a lower height then the vehicular traffic signal faces;
- Use 8 inch signal heads for far-side signals. 8 inch signal heads should only be considered if other signal heads are 12 inches in diameter for the same direction of travel.

A BICYCLE SIGNAL sign (R10-10b) shall be placed adjacent to all bicycle signal faces.

Mounting height

When newly erecting a pole for adding a bicycle signal or adding a bicycle signal to an existing pole, the following applies:

- If a bicycle signal head is mounted on a mast arm, the bottom of the housing shall be between 15 and 25.6 ft. above the pavement;
- The bottom of the signal housing of an 8 inch or 12 inch bicycle signal face that is not located over a roadway shall be a minimum of 10 ft. and maximum of 19 ft. above the sidewalk or ground. Where supplemental signing is installed below the bicycle signal face, the minimum mounting height to the bottom of the supplemental sign should be 10 ft.;
- If a 4 inch bicycle signal face is used as a near-side supplemental signal, the bottom of the signal housing should be between 4 and 8 ft. above the ground.

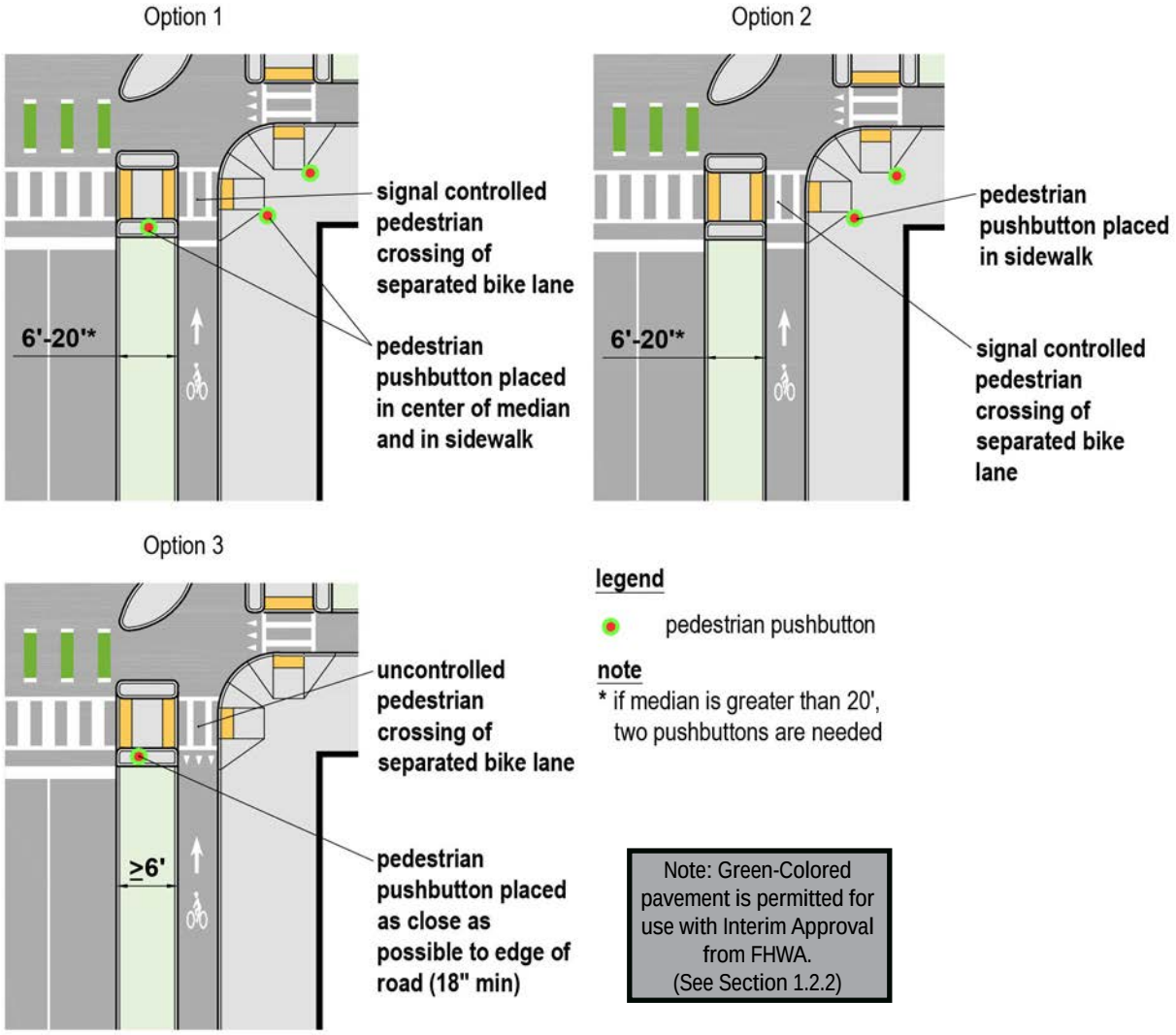
When feasible, mounting bicycle signal heads at a different height than adjacent vehicle signal heads can reduce confusion.

Considerations for placement with pedestrian signal equipment

Designers must determine if a pedestrian crossing of the separated bike lane should be controlled or uncontrolled at intersections with a separated bike lane and a street buffer that is 6 ft. or wider. For all ODOT projects, controlled crossings are preferred. When floating transit stops are present along a separated bike lane at a signalized intersection, the platform will serve as a pedestrian crossing island; as such, a second pushbutton must be placed in the buffer (see Chapter 10 for floating bus stops). The following discusses uncontrolled and controlled crossing considerations:

- **Controlled crossings** – Can be used where it is desirable to ensure bicyclists are stopped prior to the pedestrian crossing (see Option 2 and 3 in Figure 8-3). In these cases, the separated bike lane movement across the pedestrian crossing is signal controlled. The pedestrian clearance interval should be based on a crossing distance beginning/ending at the sidewalk, which will increase the signal cycle length and delay for all users. Additionally, the benefits of the forward queuing area to reduce bicyclist conflicts with turning traffic are diminished. If the street buffer is greater than 6 ft., an additional pushbutton may need to be placed in the median to meet pedestrian accessibility guidelines, such as where a floating transit stop is present (see Option 2 in Figure 8-3).

Figure 8-3: Accessible Pedestrian Pushbutton Locations with Separated Bike Lane


Option 1
signal controlled pedestrian crossing of separated bike lane
6'-20'*
pedestrian pushbutton placed in center of median and in sidewalk
Option 2
pedestrian pushbutton placed in sidewalk
6'-20'*
signal controlled pedestrian crossing of separated bike lane
Option 3
uncontrolled pedestrian crossing of separated bike lane
≥6'
pedestrian pushbutton placed as close as possible to edge of road (18" min)
legend
pedestrian pushbutton
note
* if median is greater than 20', two pushbuttons are needed
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)

- **Uncontrolled crossings** – Can be used where it is desirable to prioritize a shorter pedestrian crossing distance and maintain the ability to allow bicyclist to wait in the forward queueing area of a protected intersection (see Option 1 in Figure 8-3). In this option, the separated bike lane movement across the pedestrian crossing is uncontrolled and the pedestrian clearance interval is based on a crossing distance beginning/ending at the median (i.e., street buffer).

When the buffer is less than 6 ft. wide at an intersection with a separated bike lane, the pedestrian pushbutton should not be placed in the buffer area. In these cases, pushbutton placement should follow the layout shown for Option 3. In all scenarios, designers should ensure all proposed pedestrian ramps, pushbuttons, and signals meet current accessibility guidance, see OMUTCD Section 4E and Section 8.3.2 of this guide for additional details.

8.4.4. Signal Timing and Reducing Bicycle Delay

Existing signals are usually timed for prevailing motor vehicle speeds. Designers should evaluate minimum clearance intervals based on bicyclists' operating characteristics and make adjustments that provide the safest design for all users. Signal cycle length and signal coordination can also impact bicyclist delay, which may lead to traffic control device non-compliance. Designers should balance traffic operations and consider delay and safety impacts to all users.

A bicyclist design speed of 8 mph and acceleration of 2.5 ft./s^2, which is a typical speed and acceleration profile of a slow-moving adult bicyclist, is recommended for minimum green signal timing. A bicyclist design speed of 15 mph is recommended for red clearance interval signal timing. The designer should adjust the design speed and acceleration values as appropriate at locations where the typical bicyclist may be slower or faster moving, such as on downhill or uphill grades.

Signal Cycle Length

Signal cycle length can have a significant impact on pedestrian and bicyclist travel. Signal cycle lengths of 60 to 90 seconds are common in urban areas, as they allow frequent street crossings and can encourage more efficient street network use. In suburban areas where vehicle traffic is often consolidated on a relatively small number of arterial and collector streets, signal cycle lengths are typically longer compared to denser, urban corridors that may have a number of one-way facilities. Cycle lengths are generally between 90 and 150 seconds, though some intersections run longer cycle lengths during peak travel periods. At intersections with a longer signal cycle length, users approaching from a minor street can experience significant delays. This can result in reduced signal compliance for bicyclists where gaps are present, when bicyclists are unaware that they have been detected, or if they have not been detected at the intersection. Consideration should be given to providing shorter signal cycle lengths when feasible, or operating in "free" or fully actuated mode during off-peak periods so that the signal switches to the side street phase more quickly to minimize delays to side street users including bicyclists. However, signal cycle length reductions must not come at the cost of adequate pedestrian crossing intervals (see Section 8.3.3).

In some cases, the signal cycle length at an intersection is determined based on adjacent intersections that are part of a coordinated system described later in this section.

Bicycle Minimum Green

When an approach receives a green indication, a bicyclist waiting at the stop line needs enough time to perceive, react, accelerate, and establish themselves in the intersection before the beginning of the yellow signal indication. The recommended minimum green time for a bicyclist is long enough for a bicyclist to travel at least halfway across the intersection so that a bicyclist is visible to conflicting traffic and has established themselves in the intersection before the signal turns yellow.

Where bicyclists and motorists follow the same signal, the minimum green at an intersection should be based on the bicycle minimum green. Different minimum green time for bicyclists and motor vehicles may be established under the following scenarios:

(A) The traffic controller has the capability to set bicycle minimum green parameter;

(B) Separate detection or detection that can differentiate bicycles from motor vehicles is implemented.

When bicycle signals (either a standard traffic signal face designated for bicycle use or a bicycle signal face) are used for exclusive bicycle phases, the bicycle minimum green should be used.

Table 8-3 defines the bicycle minimum green time based on the distance from the stop line. At a minimum it is recommended "d" be defined as the distance from the stop line to the middle of the intersection. However, designers may choose a higher value of "d" up to the full width of the intersection. A larger "d" will enable a bicyclist to get farther through the intersection before the green indication ends, potentially improving bicyclist comfort when crossing the intersection.

A minimum green time based on a bicyclist traveling halfway across the intersection will typically result in a phase length long enough for a bicyclist to fully clear the intersection before the conflicting approach receives the green indication. However, at some wider crossings, the total phase time may not be sufficient. Designers should also verify that the total phase time is greater than the total time for a bicyclist starting from a stop to cross the intersection (see Table 8-4). Designers should increase the minimum green time until the total phase time is greater than or equal to the total time for a bicyclist to cross the intersection.

Note that the assumed bicycle travel speed for both minimum green time and total phase length is 8 mph. However, a higher speed may be considered for the red clearance interval, since slow moving bicyclists are not likely to enter the intersection at the end of the yellow change interval. See the discussion of "Red Clearance Interval" below.

Table 8-3: Bicycle Minimum Green Time Equation

Bicycle Minimum Green Time Equation		
$G_{min} = t + \frac{1.47v}{2a} + \frac{d+L}{1.47v}$		
Where:		
G_{min}	=	bicycle minimum green time (s)
v	=	attained bicycle crossing speed (assumed 8 mph)
t	=	perception reaction time (generally 1.5 s)
a	=	bicycle acceleration (assumed 2.5 ft/s^2)
d	=	distance from stop bar to middle of the intersection (ft)
L	=	typical length of a bicycle (6 ft)

Table 8-4: Total Phase Length, Minimum Green

Total Phase Length and Minimum Green		
$G_{min} + Y + R_{clear} \geq t + \frac{1.47\,v}{2a} \quad \frac{W+L}{1.47v}$		
Where:		
G_{min}	=	time required to attain crossing speed (s)
Y	=	yellow change interval (s)
R_{clear}	=	all-red (s)
w	=	intersection width (ft)
L	=	bicycle length (assumed 6 ft)
v	=	bicycle travel speed (assumed 8 mph)
a	=	bicycle acceleration (2.5 ft/s^2)
t	=	perception reaction time (assumed 1.5 s)

Yellow Change Interval

The OMUTCD, Section 4D.26 states that a vehicle yellow change interval should be a minimum of three seconds, which provides sufficient reaction time for a bicyclist traveling at up to 15 mph to stop before entering the intersection. When a bicycle signal (either standard traffic signal face designated for bicycle use or a bicycle signal face) are used exclusively for bicycle phases, the minimum yellow change interval of three seconds should be used.

When bicyclists and motor vehicles follow the same signal, the yellow change interval for a motor vehicle should be used, as motor vehicles will likely be traveling at higher speeds and need additional time to react, See TEM Section 403-2.

Red Clearance Interval

The red clearance interval allows for a roadway user that legally entered the intersection at the end of the yellow change interval additional time to complete their movement prior to crossing movements receiving a green indication. Designers should determine where a bicyclist would be positioned if they entered the intersection at the end of the yellow interval. For shorter red clearance intervals, the bicyclist may not be visible to motorist stopped on the conflicting approach waiting for a green indication. In these instances, designers should lengthen the red clearance interval so that a bicyclist will have established themselves in the intersection or traveled beyond the conflict point with a conflicting approach (see Figure 8-4).

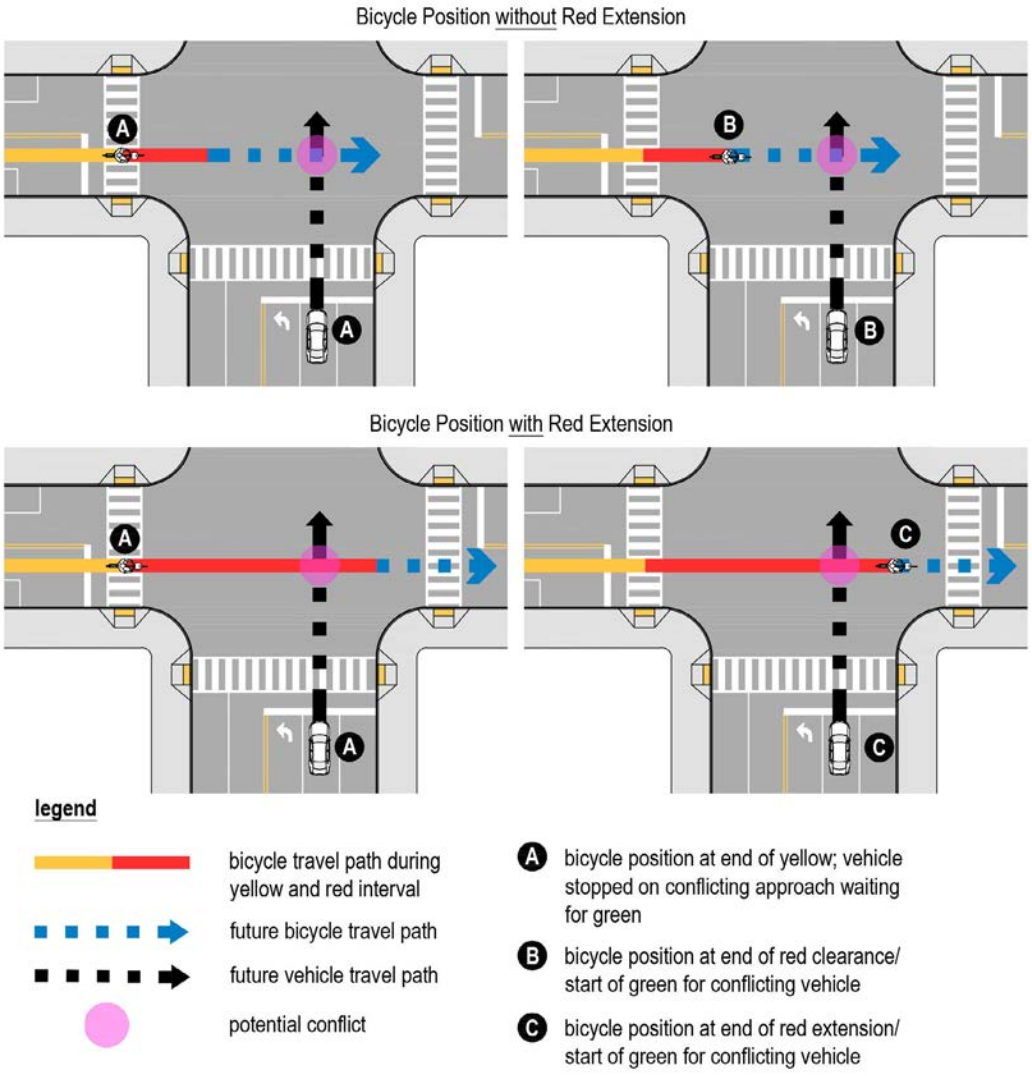
As previously mentioned in the "Bicycle Minimum Green" section, a higher design speed may be considered for the red clearance interval when taking bicycles into account. If a bicyclist determines not to stop during the yellow change interval, they are likely accelerating to clear the intersection. In this case, a higher design speed of 15 mph may be considered for the red clearance interval. Such a calculation is not likely to significantly change the overall interval if rounded to the nearest second, but it may reduce the red clearance from two seconds to one second, allowing that time to be applied elsewhere in the cycle length.

When bicyclists on the major street intend to use a two-stage bicycle turn box place in line with the lanes of the minor street approach, the designer should consider extending the red clearance interval because the bicyclist must slow to access the bicycle turn box. If the subsequent phase includes side street through traffic, a longer red clearance may be necessary to accommodate bicycle traffic entering the box. However, if the subsequent phase does not include side street through traffic (e.g., lagging left turn on the major approach), a longer red clearance would not be necessary.

Bicycle Green Extension

In locations where bicycle volumes are heavy during a particular time of day, additional green time may be needed. In these cases, the approach may include a detector at the stop line or in advance of the stop line to extend the green interval in order to allow bicycle traffic to move through the intersection. The length of the extension should be determined by the speed of bicyclists, the detector distance from the stop line, and the amount of extension time that can be provided. Once the phase has begun, each bicyclist will extend the green time for each bicycle detected up to the maximum green.

Figure 8-4: Bicycle Position During Red Clearance


Bicycle Position without Red Extension
A
A
B
B
Bicycle Position with Red Extension
A
A
C
C
legend
bicycle travel path during yellow and red interval
future bicycle travel path
future vehicle travel path
potential conflict
A bicycle position at end of yellow; vehicle stopped on conflicting approach waiting for green
B bicycle position at end of red clearance/ start of green for conflicting vehicle
C bicycle position at end of red extension/ start of green for conflicting vehicle

Signal Coordination Considerations

Corridors with coordinated signals are often timed to progress motor vehicles at speeds which are significantly faster than typical bicycle travel. Consequently, in these cases, most bicyclists will not gain progression benefits.

Cycle length is usually selected based on the needs of the largest or most congested intersection. These signal cycle lengths are sometimes longer than optimal for smaller or less busy intersections and can result in higher delays for users on side streets. These side streets are often more comfortable for bicyclists, assuming they provide reasonable network connectivity and comfort for bicycles. Significant intersection delays degrade the value of these corridors and can result in reduced signal compliance when traffic gaps are available. This can be a significant barrier at bicycle

boulevard crossings or shared use paths where there may be an expectation of a higher level of service for bicycle travel (See Chapters 5 and 6).

To offset these challenges, on streets that are designed to accommodate bicyclists, designers should consider the following:

- **Half signal cycle lengths or a shorter corridor-wide signal cycle length during lower volume and off-peak periods**. On coordinated corridors with semi-actuated signalized intersections (i.e., detection on the side street), signals could operate in "free," or uncoordinated mode, to reduce delays on the side streets. Designers should consider signal spacing, traffic volumes, and delay for all users when evaluating whether to run a signal in "free" or uncoordinated operation. In signal networks with fixed time operation and lower cycle lengths (90 seconds or less), it may be preferred to maintain coordination.
- **Progression speeds closer to bicycle operating speeds to support and encourage bicycle traffic on the coordinated corridor.** These are referred to as "Green Wave" progressions for bicycles. They allow bicyclists to operate at a consistent speed, reduce stopping, and improve compliance. Common green wave progression speeds are between 12 and 15 mph. This speed can vary depending on corridor geometry and geography (e.g., grade, sight distance). A "Green Wave" encourages slower travel speeds for motor vehicles, which improves safety for all roadway users. Where a "Green Wave" is provided, SIGNALS SET FOR XX MPH (I1-1) signs may be posted to advise road users of the recommended speed.

"Green Wave" progression would be most appropriate on bikeway corridors (e.g., bicycle boulevards) with reasonable volumes of bicycle activity. Lowering progression speeds could needlessly increase delay for motor vehicles and transit passengers, so the installation of "green wave" progression should consider the effects on all travel modes.

In some instances, bicycles may be traveling in the opposite direction of signal progression. For example, there may be counterflow movement of a two-way separated bike lane or side path. There may also be a designated bike lane traveling the opposite direction of motor vehicle traffic on a one-way street. These scenarios should be designed with signal progression similar to a conventional two-way street.

8.4.5. Signal Phasing for Managing or Reducing Conflicts

Traffic signal phasing is an essential tool for managing and reducing conflicts at intersections. Signal phasing should be considered in conjunction with intersection design treatments described in Chapters 3 through 9, as appropriate.

Although eliminating conflicts between bicyclists and motorists provides the greatest safety benefit, signal phasing should balance delay to all users, signal cycle length, and the risk of conflicts. Designers should assess the number of right and left-turning motorists across bikeways during the peak hour to identify when a protected or partially protected bicycle phase may be considered. Table 8-5 identifies thresholds for when a protected phase or leading bicycle interval for a separated bike lane or side path may be appropriate to improve safety at an intersection. It may also

be appropriate to reduce the threshold volumes on higher speed roads.

In addition, designers shall consider providing separate signal phases for the following situations:

- Locations with multiple left or right turn lanes;
- Where sight obstructions limit bicycle visibility;
- At locations where bicycle volumes and/or parallel pedestrian volumes are high and turning motorists are unable to find appropriate gaps;
- At locations where more than 5 percent of the turning traffic volume is heavy vehicles;
- Locations where motorists may turn across the bikeway at speeds over 30 mph or on roads with posted speeds of 35 mph or greater.

Table 8-5: Hourly Turning Traffic Thresholds for Time-Separated Bicycle Movements

Hourly Volume Thresholds for Separate Turn Phases		
	Left Turn Crossing One Oncoming Lane	Left Turn Crossing Two Oncoming Lanes
One-Way Separated Bike Lane	≥ 100 ≥ 150*	≥ 50 ≥ 150*
Two-Way Separated Bike Lane or Sidepath	≥ 50 ≥ 100*	ANY ≥ 100*

*Threshold also applies to left turns on one-way streets

Protected phases and turning restrictions may be implemented on a permanent basis, through actuation, or during specific hours. If only one approach meets the criteria above, consider a treatment to address that approach before considering an intersection-wide treatment (e.g., evaluate a protected only left-turn phase if only the left turning volume threshold is exceeded but not the right turning volume threshold).

Where Table 8-5 or the list of criteria indicates that one or more vehicular turning movements should be phase separated from bicyclists, but a separated phase is not feasible or desirable, designers should consider a leading bicycle interval and/or a flashing yellow arrow. Additional treatments are discussed in Section 8.4.5.1.

Conventional, buffered, and raised bike lanes will follow either traffic signals or pedestrian signals, as directed. Where right turn only lanes are present (see Section 6.5.3) a conventional or buffered bicycle lane cannot be placed to the right of the turn lane. If a bicycle lane must be placed to the right of a right turn lane for safety and to accommodate the design user (i.e., high volume of vehicles crossing the bicycle lane to turn right), designers shall convert the bicycle lane to a raised bike lane or separated bike lane and follow the principles set forward in this section. Phase separation is required for a raised bicycle lane located to the right of a right turn lane (see Section 6.5.4).

8.4.5.1 Phasing Schemes

Designers may incorporate a bicycle signal phase at a signalized intersection to reduce potential conflicts between bicyclists and motor vehicles. Designers should consider both the operational and safety impacts of signal phasing changes at an intersection. Designers should be aware that a phasing scenario may necessitate a separate motor vehicle turn lane and an additional phase, which may increase delay for some users, including bicyclists. Fully separated movements may require longer signal cycle lengths, which may result in reduced user compliance with signal indications and therefore increase potential for conflict. However, the need to protect bicyclists from turning conflicts should be considered a higher priority over reducing bicyclist delay.

Many of the signal phasing options described in Section 8.3.4 for pedestrians can also be adapted to eliminate or manage conflicts between bicyclists and motorists. This section describes four schemes of bicycle signal phasing that employs some of the techniques discussed in Section 8.3.4. There are numerous phasing options available to designers, and not all options are possible depending on the type of bikeway provided at the intersection (e.g., conventional bike lane, raised bike lane, separated bike lane). These schemes are intended to provide examples of some of the options available.

Exclusive Bicycle Phase

This phasing scheme represents a fully separated bicycle movement. All motorized vehicle movements, including conflicting vehicle turns across the bikeway, are restricted during the exclusive bicycle phase. Exclusive turn lanes for the conflicting vehicle turns are not required since all vehicle movements are stopped. Some pedestrian movements may be allowed during the exclusive bike phase.

If bicyclists move independently of pedestrians, this phasing requires the use of a standard traffic signal face designated for bicycle use or a bicycle signal face consistent with IA-16 that is separate from the motor vehicle signal. Alternatively, bicyclists may be directed to follow pedestrian signals during a shared, protected bicycle and pedestrian phase. In this case, a [BICYCLE] USE PED SIGNAL sign (R9-5) should be installed. R9-5 sign installation should only be considered for use on shared use paths, raised bike lanes, or separated bike lanes. Right (or Left) turn on red shall be prohibited during the protected bicycle phase. Depending on the signal phasing, a blank out or static NO TURN ON RED (R10-11) sign shall be provided.

Where a pedestrian-only phase is provided, a text-based BICYCLE MAY USE PED SIGNAL sign may be used to allow bicyclists to use the pedestrian-only phase. See Section 8.4.1.

Depending on right and left turn volumes, the exclusive bike phasing scheme is more likely to have an impact on motor vehicle operations. To accommodate queues or an increase in signal cycle, consider extending turn lane storage lengths, if feasible.

Concurrent Protected Bicycle Phase

This phasing scheme also represents a protected-only bicycle movement. The bicycle phase runs concurrently with parallel through motor vehicle phases, but conflicting turns across the bikeway are restricted. Right and left-turn movements across the bikeway operate under a protected-only phase. Exclusive turn lanes for conflicting vehicle turns will be necessary.

In this phasing scheme, a bicycle shall be controlled by a bicycle signal head separate from the vehicle signal. See Section 8.4.1 for signal indication options. Right (or left) turns on red shall be prohibited during the protected bicycle phase. Depending on the signal phasing, a blank out or static NO TURN ON RED (R10-11) sign shall be provided.

Depending on left and right turning volumes, this phasing scheme may have an impact on motor vehicle operations, especially for the turning movements across the bikeway. Turn lane storage lengths may need to be extended to accommodate queues; reducing split times for other phases or increasing signal cycle length may also be necessary. This phasing scheme can be effective for bikeways along streets with high through movement volumes and low turning volumes.

Leading Bicycle Interval

At locations where bicycle volumes and/or motor vehicle turning volumes are lower than the threshold shown in Table 8-5, or at locations where a bicycle protected phase is not feasible, there may be benefits to providing a leading bicycle interval (LBI) or leading through interval (LTI). For LTI, designers should refer to Section 8.3.4.1. This phasing scheme represents a partially separated bicycle movement. Leading intervals are typically between three and eight seconds long and occur in advance of the green indication for turning motor vehicles. For pedestrians, if a protected intersection is used and bicyclists are allowed to queue in front of the crosswalk, the leading interval may be reduced as bicyclists will be positioned ahead of adjacent motor vehicle lanes and, by design, will be able to establish themselves in the intersection sooner with a short leading interval. Because it only requires a few seconds, a leading bicycle interval may have only a minor impact on motor vehicle operations and, in general, does not require a longer signal cycle length. However, on higher travel corridors, the designer may wish to perform a microsimulation of the proposed phase plan prior to implementation to estimate the difference in travel time between scenarios.

An LBI allows a bicyclist to enter the conflict area prior to a turning motorist, improving their visibility as they cross the intersection. In some cases, an LBI may allow bicyclists to clear the conflict point before motor vehicles enter the intersection. A parallel LPI may also be considered where there is a parallel pedestrian crossing. When a protected left turn phase is provided, it should occur as a lagging phase to prevent left turning vehicles continuing to cross during the LBI. Designers should also avoid the “Yellow Trap” (see TEM [403-9]) when providing a lagging turn phase.

In this phasing scheme, a bicycle must be controlled by a signal head that is separate from the motor vehicle signal. Any of the signal indication options from Section 8.4.1 may be used to control bicyclist movements for an LPI except for the bicycle signal face (per IA-16). Right (or left) turns on red shall be prohibited during the LBI under this scenario. At locations where additional motor vehicle capacity is desired or there are concerns about compliance with a static sign, the use of a blank out NO TURN ON RED (R10-11) sign may be considered.

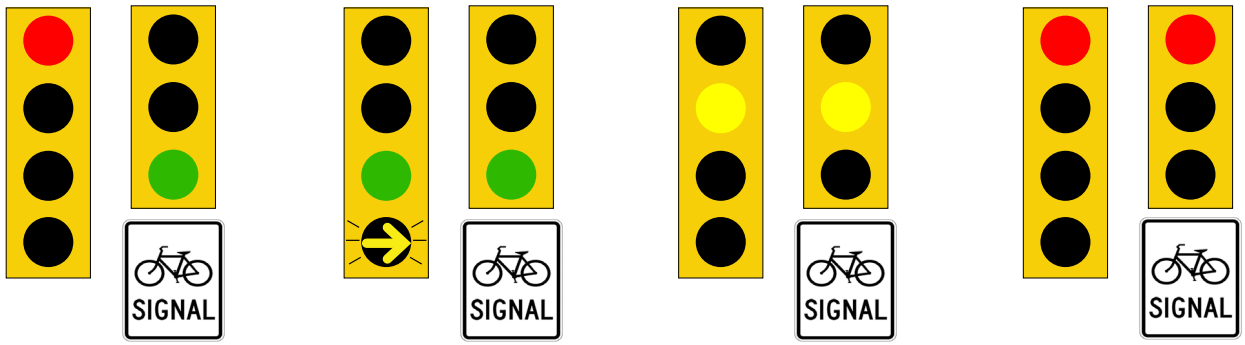
LBIs only assist bicycles waiting at the stop line at the beginning of the green interval. They do not provide any protection to bicyclists who arrive after the LBI has ended. Because an LBI includes permissive turns while bicyclists may proceed through, designers should provide signing or signal

indications to communicate that mutual yielding (see Section 3.4) conditions will apply. One possible phasing option for an LBI is provided in Figure 8-5. Designers can also consider regulatory signs, such as the R10-15 series TURNING VEHICLES YIELD TO BICYCLISTS (AND PEDESTRIANS) (see Section 8.8.1), and warning signs stating WATCH FOR TURNING VEHICLES. Section 4D of the OMUTCD provides additional signal information using protected and permissive signal design for right and left turns.

Concurrent Bicycle Phase with Permissive Vehicle Turns

This phasing option represents a common scenario at most intersections where bicyclists in a shared lane or bike lane are not provided any exclusive time in the intersection. In this case, bicyclists are crossing the intersection concurrent with parallel through motor vehicles, and motorists may make permissive turns that cross their path if separate right turn lanes are not provided. This phasing scheme has the lowest impact on motor vehicle operations but may not adequately address turning motorist/through bicyclist conflicts. Any of the signal indication options from Section 8.4.1 may be used to control bicyclist movements with concurrent bicycle phases except for the bicycle signal face (per IA-16). Designers should apply the following treatments as appropriate:

Figure 8-5: Signal Phasing Scheme with LBI and FYA



- Flashing Yellow Arrows (see Section 8.3.4.3);
- Regulatory signs, such as the R10-15 series TURNING VEHICLES YIELD TO BICYCLISTS (AND PEDESTRIANS) (see Section 8.8.1);
- Warning signs for bicyclists to WATCH FOR TURNING VEHICELES;
- An offset bicycle crossing to create space for yielding (see Chapter 6);
- Geometric treatments to reduce vehicle speeds and increase sight distances (see Chapters 3 and 7).

8.5 Toucan Crossings with Traffic Signals

A Toucan crossing, originating from the phrase 'two can cross,' is a traffic signal complemented by a geometric design treatment that restricts some motor vehicle movements while providing a signalized bicycle and pedestrian crossing. The pedestrian crossings may be located in their traditional location, from corner-to-corner, or may be consolidated to one crossing of the roadway

adjacent to the bicycle crossing (see Figure 8-6). A consolidated crossing may reduce conflicts with motorists, but it requires pedestrians to cross away from their traditional line of travel and require a larger central island size to accommodate them while maintaining separation from bicyclists.

This design stops motor vehicle traffic on the major street during the entirety of the bicyclist and pedestrian crossing. These intersections restrict through and left turn motor vehicle movements from the side street, creating a protected crossing for bicyclists. Motorists are permitted to make a right turn movement from the side street, thus removing it from signal control.

This design may be considered for major arterial crossings where it is not desirable to provide a PHB or a full traffic signal. A typical application for a Toucan crossing is where a bicycle boulevard crosses an arterial street. Toucan crossings may also be used at T-intersections.

8.5.1. Geometric Design Features and Signal Equipment Placement Considerations

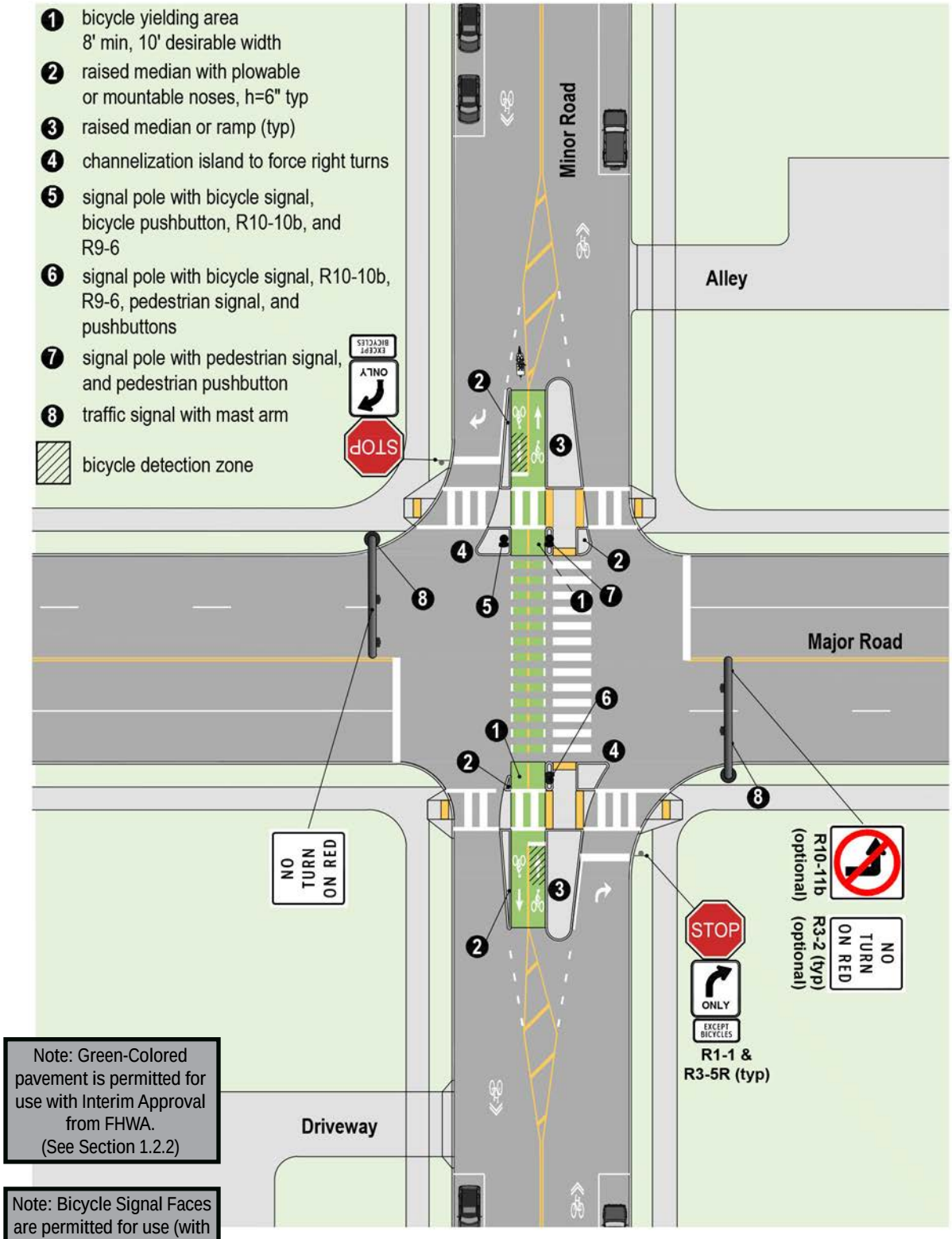
There are several key features of this type of crossing (See Figure 8-6):

- Minor street center medians for bicyclist separation from motor vehicles and space for bicycle signal placement;
- Raised median or raised bike lane to create a queueing area for bicycles;
- Pedestrian crosswalks on all legs or consolidated to one crossing of the major street;
- Channelization island to restrict motorist through and left turns from minor street;
- Pedestrian signals for pedestrians crossing motor vehicle movements;
- Pedestrian signals for pedestrians crossing signalized bike lanes (if a two-stage crossing is provided);
- Bicycle signals for bicycles crossing the major street.

Parking restrictions on the minor street may be necessary within 75 ft. to 100 ft. from the intersection to accommodate motorist shifting tapers and space for the bicycle queuing area and pedestrian crossing island. In addition, median noses of channelization islands should be plowable. Due to the center of the roadway alignment for the bicycle movement, green-colored pavement may be used to delineate the bicycle lane and crossings.

Where pedestrians cross from corner-to-corner, the pedestrian pushbuttons are needed for crossings from all four corners and actuation for bicyclists would be separate. Where pedestrians crossing to the center of the intersection and cross parallel to the bicycle crossing, all pedestrian and bicycle pushbutton equipment is located within the raised islands and the number of pedestrian pushbuttons is reduced.

Figure 8-6: Toucan Crossing Example


1 bicycle yielding area 8' min, 10' desirable width
2 raised median with plowable or mountable noses, h=6" typ
3 raised median or ramp (typ)
4 channelization island to force right turns
5 signal pole with bicycle signal, bicycle pushbutton, R10-10b, and R9-6
6 signal pole with bicycle signal, R10-10b, R9-6, pedestrian signal, and pushbuttons
7 signal pole with pedestrian signal, and pedestrian pushbutton
8 traffic signal with mast arm
bicycle detection zone
Minor Road
Alley
Major Road
Driveway
NO TURN ON RED
R10-11b (optional)
R3-2 (typ) (optional)
NO TURN ON RED
STOP
ONLY
EXCEPT BICYCLES
R1-1 & R3-5R (typ)
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)
Note: Bicycle Signal Faces are permitted for use (with protected-only phases) with Interim Approval from FHWA. (See Section 1.2.2)

8.5.2. Toucan Crossing Signal Timing Considerations

A Toucan crossing's signal timing should accommodate both pedestrian and bicycle crossings and their unique operating characteristics. Since the pedestrian crossing and bicycle crossings are separated, there is flexibility in how the signalized crossing is timed:

- When a bicyclist is detected, the bicycle signal should be activated, and the total phase length should be based on the signal timing guidance in Section 8.4.4;
- When a pedestrian is detected, the pedestrian signal should be activated and the total phase length (WALK and FLASHING DON'T WALK) should be based on pedestrian clearance times in the OMUTCD. The bicycle signal should also be activated with the pedestrian phase since the bicycle signal phase length is less than the pedestrian phase length and there are no conflicts between the two phases in this timing plan;
- Designers have the option of activating the pedestrian signal when a bicyclist is detected to reduce potential pedestrian delay. This is a particularly important consideration if the pedestrian crossing is moved to the center of the intersection; as described in Section 8.5.1.

Designers should consider the impact of the signal activation in a coordinated signal system. The guidance in Section 8.6 for PHBs in coordinated signal systems will also apply to Toucan signals.

8.6 Pedestrian Hybrid Beacons

A Pedestrian Hybrid Beacon (PHB) is a type of traffic beacon that facilitates a roadway crossing by stopping major street traffic with a red indication. PHBs are similar to pedestrian signals and are used in variety of applications to improve crossing safety and reduce crossing delay for pedestrians and bicyclists. These devices may be used in a variety of contexts (urban, suburban, and rural).

The decision to provide a PHB at either an intersection or a mid-block crossing is discussed in Sections 4.4.3, 6.4, and 8.2. PHB operation is described in the OMUTCD (Section 4F.03).

8.6.1. General Design Considerations

In addition to the standards specified in the OMUTCD (Sections 4F.01 and 4F.03), the following design considerations may be applicable:

- Pedestrian signals shall be provided in accordance with Section 8.3.1;
- Pedestrian pushbuttons shall be provided in accordance with Section 8.3.2;
- When PHBs are installed for bicycle use, refer to guidance in Section 8.6.3;
- Parking and other sight obstructions should be prohibited for at least 100 ft. in advance of and at least 20 ft. beyond the marked crosswalk, or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance;
- A W11-2 (PEDESTRIAN), S1-1 (SCHOOL), or W11-15 (TRAIL) crossing warning sign should be provided on the mast arm overhead or to the right with a diagonal downward arrow (W16-7P) plaque;

- A similar sign to those listed in the previous bullet point with an "AHEAD" plaque (W16-9P) may be installed in advance of a PHB;
- Warning beacons may be installed in advance of PHBs, though if installed, they should only activate when the PHB is not in "dark" mode;
- An R10-23 (CROSSWALK, STOP ON RED) sign, mounted overhead on the PHB mast arm, shall be included for each major street approach at a PHB.

8.6.2. Pedestrian Hybrid Beacon Timing & Reducing Delay

Designers should follow the pedestrian signal phase timing guidance in Section 8.3.3 for PHBs. Designers may consider inserting a steady red clearance interval before the walk interval begins. At locations where both bicyclist and pedestrians use PHBs, the crossing interval should be timed based on pedestrian crossings design parameters and speeds. Pedestrian signal timings will most likely provide sufficient time for a bicyclist to clear the entire intersection. See Section 8.4.3 for additional design guidance for signal timing for bicyclists.

To minimize delay for both pedestrians and bicyclists and increase compliance, a PHB should operate in isolation from other intersections (i.e., in "free operation"), if possible. The maximum length of the "dark until activated" period after activation of the pushbutton should be as short as feasible (i.e., less than 30 seconds).

If a PHB is installed within a coordinated system, the designer may choose to run the timing plan in coordination. While not always desirable from a non-motorist user perspective, coordination may be necessary if a PHB is installed near the intersection of two major streets (less than 750 ft.). To mitigate potential pedestrian and bicycle non-compliance, the designer may consider using a half cycle length to reduce pedestrian and bicycle delay.

8.6.3. Considerations for Bicycle Traffic

When installed, PHBs should be located to respond to bicyclist desire lines with respect to crossing major roadways. Bicyclists should not be expected to significantly detour from their direct travel path to reach an intersection or mid-block location with a PHB, as this can create additional delay for bicyclists and may encourage unwanted crossing behaviors.

Pedestrian hybrid beacons intended for bicyclist use should provide clear and unambiguous messages to bicyclists, and beacon actuation should be accessible to bicyclists. Where PHBs are provided, side street motor vehicle traffic is stop sign controlled, pedestrian traffic is pedestrian signal controlled, and bicycle traffic may be controlled by either of the following:

- Stop sign – bicyclists cross as motorists at intersections;
- Pedestrian signal – bicyclists are directed to cross as a pedestrian.

At such intersections, bicyclists have the choice to use the stop sign if there are adequate gaps in traffic on the major road. If there are not adequate gaps or if a bicyclist would be more comfortable using the pedestrian signal, they can activate the PHB and wait for the WALK indication. The

following discussion provides contextual considerations for each crossing strategy (see Section 8.4.2 for detection guidance).

Stop Sign Control

After stopping at the intersection and finding an adequate gap in traffic, the bicyclist may cross the street. This option minimizes bicyclist crossing delays during periods where there are sufficient gaps in major street traffic. During periods of higher traffic volume, bicyclists may exhibit unwanted crossing behavior if gaps in traffic are inadequate and it is not clear how to activate the PHB (see Section 6.4). For this reason, bicyclists should be given the option of using the pedestrian signal control. The PHB should be designed to clearly communicate how a bicyclist can activate the beacon, as described below.

Pedestrian Signal Control

A bicyclist should be provided with one or more of the following options to activate the beacon:

- Curbside pushbutton (this pushbutton is in addition to the pedestrian pushbutton located at or near the top back of the pedestrian ramp);
- Opportunity to exit the roadway to access the pedestrian pushbutton via a curb ramp to the sidewalk;
- Passive detection in the location where bicyclists are likely to operate.

The BIKES USE PED SIGNAL sign (OMUTCD R9-5) should be mounted adjacent to the pedestrian signal heads. If passive detection is used at an intersection, the detection should be designed to discern between a bicycle and motor vehicle, or a bicycle lane or separated bike lane should be provided so a motorist does not activate the PHB. See Section 8.4.2 for additional design guidance on bicycle detection.

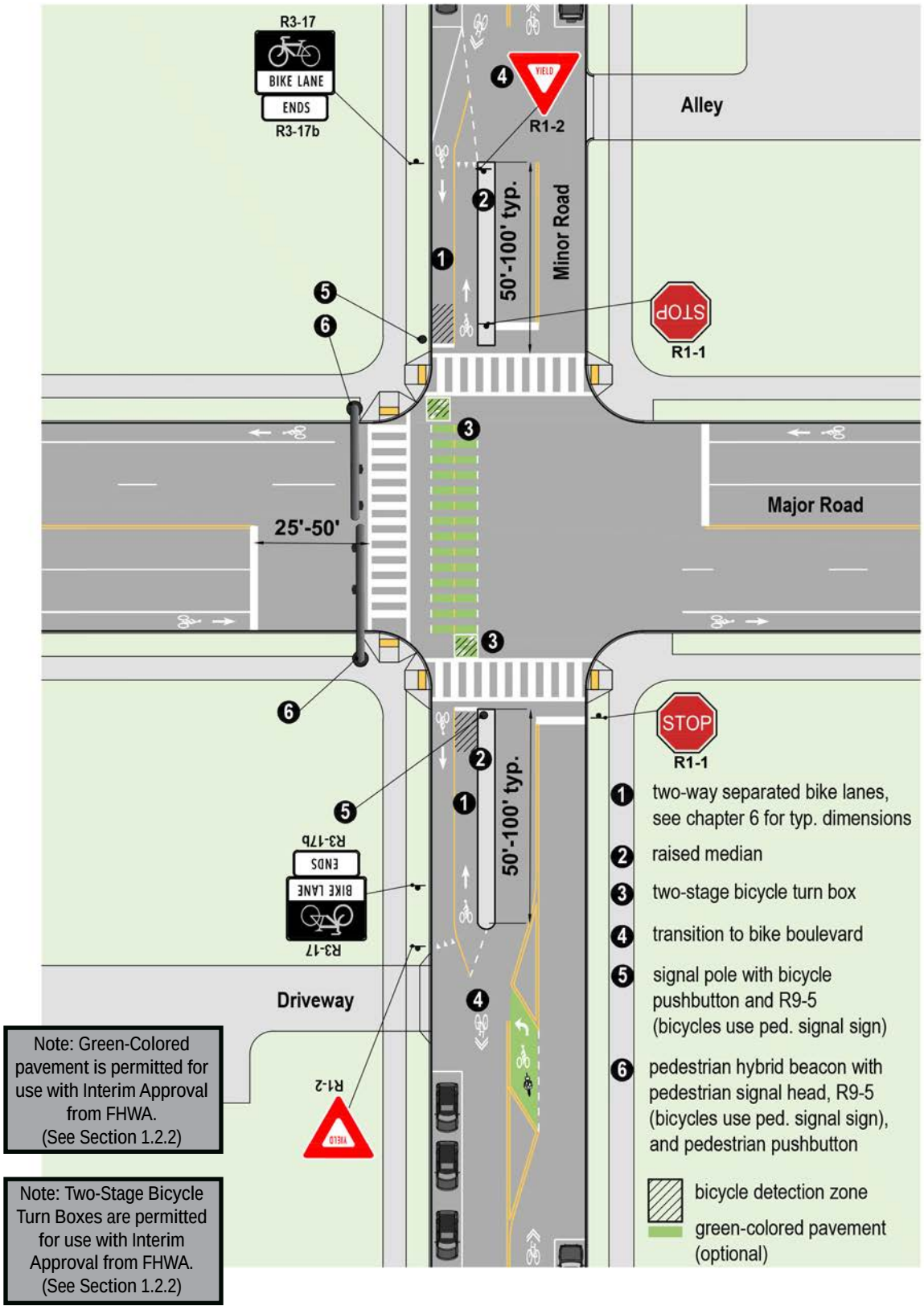
Pedestrians and bicyclists are not legally allowed to start crossing during FLASHING DON'T WALK. If a bicyclist perceives that they can clear the intersection, they might enter crosswalks during this phase. During FLASHING DON'T WALK at a PHB, motor vehicles typically have an alternating "wig-wag" red indication and can proceed through the intersection if it is clear. Given the higher speed of a bicyclist compared to a pedestrian, it may be difficult for a motorist to see the bicyclist. At locations with higher volumes of bicyclists. it may be desirable to consider a full traffic signal.

At a PHB, designers may consider creating a separated bicycle lane approaching an intersection and cross bicyclists parallel to the crosswalk. To minimize conflicts with merging or turning motorists near the intersection, it is recommended the bicyclists be channelized into a separated bicycle lane 50 ft. to 100 ft. in advance of the intersection (see Figure 8-7).

8.7 Warning Beacons

Warning Beacons are yellow flashing lights that supplement warning signs, or in some cases regulatory signs, to provide advance notification of a confined space (such as a bridge or tunnel) or shared use path crossing where bicyclists may be present. Yellow Beacons used as warning

Figure 8-7: Pedestrian Hybrid Beacon at High Volume Major Road


R3-17
BIKE LANE
ENDS
R3-17b
VIELD
R1-2
Alley
Minor Road
50'-100' typ.
STOP
R1-1
Major Road
25'-50'
Driveway
Note: Green-Colored pavement is permitted for use with Interim Approval from FHWA. (See Section 1.2.2)
Note: Two-Stage Bicycle Turn Boxes are permitted for use with Interim Approval from FHWA. (See Section 1.2.2)
1 two-way separated bike lanes, see chapter 6 for typ. dimensions
2 raised median
3 two-stage bicycle turn box
4 transition to bike boulevard
5 signal pole with bicycle pushbutton and R9-5 (bicycles use ped. signal sign)
6 pedestrian hybrid beacon with pedestrian signal head, R9-5 (bicycles use ped. signal sign), and pedestrian pushbutton
bicycle detection zone
green-colored pavement (optional)

devices shall not be installed without an appropriate warning or regulatory sign. See the OMUTCD (Section 4L.03) for additional details.

8.7.1. Active Warning Beacons

Active Warning Beacons are actuated yellow flashing lights that supplement warning signs to provide advance notification of a specific roadway feature (tunnel entrance, pedestrian crossing, etc.). Beacons may be activated either passively (e.g., video detection, radar detection, by time of day) or actively by using a pushbutton.

One example of this application is a bridge with limited sight distance and lacking bicycle specific infrastructure. In this scenario designers may consider a custom legend warning sign "BIKES ON BRIDGE WHEN FLASHING" with a beacon timed to flash long enough for a bicyclist to traverse the facility. Similar applications may be appropriate to warn motorists of unexpected or less visible pedestrians or bicyclists on facilities such as in tunnels or on roads with significant horizontal or vertical curvature. See Figure 8-8 for an example of warning beacon applications.

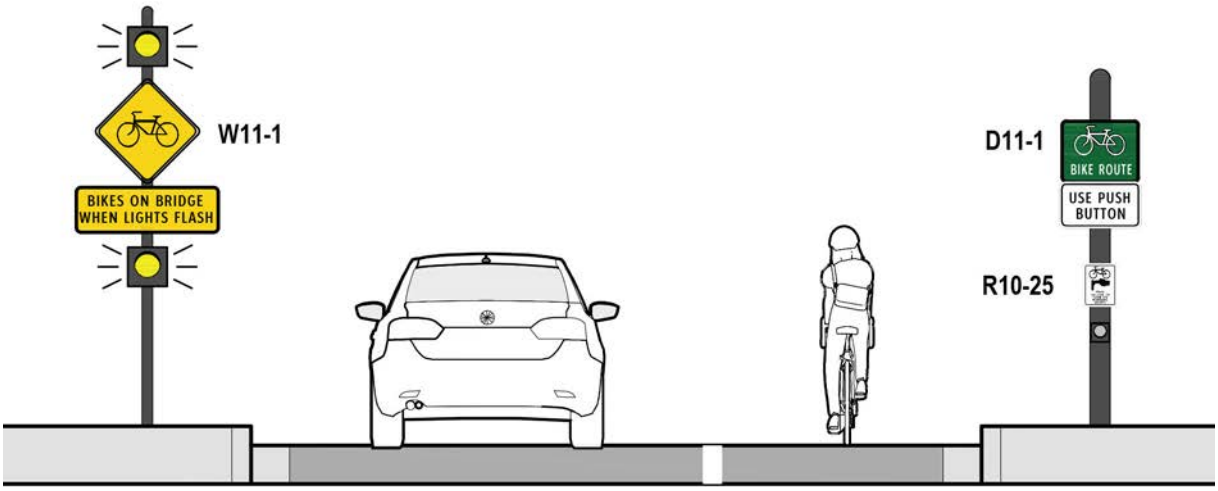
When used at uncontrolled crossings, active warning beacons are most effective along streets with three or fewer travel lanes and posted speed limits at or below 35 mph. Research has found yielding rates of 45% can be achieved at locations with these characteristics.[5]

For the design of Active Warning Beacons, designers should reference the following:

- Flashing Beacons – OMUTCD (Section 4L) and TEM (405)
- Warning Signage – OMUTCD (Section 2C)
- Detection – Sections 8.3.2 and 8.4.2

Flashing beacons may be used in a number of different applications for bicycles and pedestrians. However, use of passive, continuously flashing beacons is not recommended, as indiscriminate use can degrade their effectiveness and affect the usefulness of other flasher locations.

Figure 8-8: Active Warning Beacon Example



8.7.2. Rectangular Rapid Flashing Beacons (Interim Approval)

Rectangular Rapid Flashing Beacons (RRFBs) are user-actuated, high-intensity yellow LEDs that flash in a rapidly repeating sequence. Like Active Warning Beacons, RRFBs may supplement crossing warning signs. However, RRFBs, installed at appropriate locations, can achieve high driver yielding rates. Research has shown that RRFBs can achieve motorist yielding rates between 80 and 100 percent both during the day and during periods of darkness when installed under appropriate conditions.[6] Designers should follow the guidance in Section 4.4.3 and Section 6.4 for when an RRFB may be an appropriate treatment.

While RRFBs have been used on roadways with posted speeds 45 mph and above and on roads with more than four travel lanes, caution should be used in these applications as driver yielding percentages may be lower compared to lower speed and volume scenarios.

RRFBs may also be beneficial at multi-lane roundabout exits where motorist yielding compliance may be poor and gaps are infrequent during peak hours (see Section 9.4.4). RRFBs may be used per FHWA Interim Approval 21 (IA-21).

The general crossing design and standards of an RRFB will be the same as for a crossing without an RRFB (see OMUTCD [Section 2C] for crossing sign types, sizes, and placement). In addition, the following design considerations apply to RRFB installation:

- When used, RRFBs shall supplement post-mounted W11-2 (PEDESTRIAN), S1-1 (SCHOOL), or W11-15 (TRAIL) crossing warning signs with a downward diagonal arrow (W16-7P) plaque, or an overhead-mounted W11-2, S1-1, or W11-15 crossing warning sign, located at or immediately adjacent to an uncontrolled marked crosswalk. The RRFB shall be installed on the same support as the associated crossing warning sign and plaque.
- For any approach where RRFBs are used to supplement post-mounted signs, a minimum of two (2) W11-2, S1-1, or W11-15 crossing warning signs (each with an RRFB unit and a W16-7P plaque) shall be installed at the crosswalk, one on the right-hand side of the roadway and one on the left-hand side of the roadway. On a divided highway, the left-hand side assembly should be installed on or within the median, if practical, rather than on the far left-hand side of the highway. Careful consideration needs to be given to RRFB installation with especially wide medians (20 ft. or greater) where prevailing speeds are 45 mph or greater.
- Except for crosswalks across the approach to, or egress from, a roundabout, an RRFB shall not be used for crosswalks across approaches controlled by YIELD signs, STOP signs, traffic control signals, or pedestrian hybrid beacons.
- RRFBs shall be pedestrian or bicycle actuated. Pushbuttons are the most common method, though passive detection methods such as motion or break-beam sensors may be appropriate in locations where they will not erroneously activate for those not wishing to

cross the street. See Sections 8.3.2 and 8.4.2 for design guidance on pedestrian and bicycle detection, respectively.

- The RRFB unit associated with a post-mounted sign and plaque may be located between and immediately adjacent to the bottom of the crossing warning sign and the top of the supplemental plaque or within 12 inches above the crossing warning sign. If the RRFB unit is supplementing an overhead-mounted sign, the RRFB unit shall be mounted directly below the bottom of the sign.
- RRFB timing shall be based on the procedures provided in the OMUTCD (Section 4E.06) for pedestrian clearance timing.
- When considering additional enhancements, such as crossing islands or additional signage, designers should follow the guidance in Table 4-5. In addition, the following should be considered:
- It is preferable to erect crosswalk signage on the far-side of crosswalks less than 20 ft. in width. This placement helps ensure that sightlines between pedestrians and motorists are not obstructed.
- Where sight distance approaching the crosswalk where RRFBs are installed is less than deemed necessary by the engineer, an additional RRFB may be installed on that approach in advance of the crosswalk. This RRFB would supplement a W11-2 (Pedestrian), S1-1 (School), or W11-15 (Trail) crossing warning sign with an AHEAD (W16-9P) or distance (W16-2P or W16-2aP) plaque. If an additional RRFB is installed in advance of the crosswalk, it shall supplement, not replace, the RRFBs located at the crosswalk.
- If a speech pushbutton information message is used in conjunction with an RRFB: a locator tone shall be provided, the audible information device shall not use vibrotactile indications or percussive indications, and the message should say, “Yellow lights are flashing.” The message should be spoken twice.
- On four or six lane streets, RRFBs produce higher driver yielding rates when mounted in the median (or overhead) as well as on the right edge of the roadway in combination with advanced stop or yield lines.
- RRFBs may be solar powered and communicate with other assemblies via radio. This may eliminate the need for a power supply and/or conduit between the units, though the designer needs to ensure proper overhead lighting is present at the crossing.
- Unless RRFBs are specifically designed as warning devices for bicycle use, flashing operation should be timed for pedestrians. The flashing operation following each actuation should be based on the OMUTCD procedures for timing of pedestrian clearance times for pedestrian signals. When installed for both pedestrians and bicyclists, doing so will provide sufficient time for bicyclists to clear the roadway.

8.8 Warning and Regulatory Signs

The following section provides guidance for traffic control signs, which can improve pedestrian and bicyclists' safety and operation for all types of facilities. This guidance supplements the OMUTCD for these treatments. Per the OMUTCD, all signs must be legible and color distinguishable during dark and daylight conditions. This can be accomplished with external illumination or by using retroreflective materials.

8.8.1. Crossing and Conflict Signage

Pedestrian and Bicycle Crossing Warning Signage

Warning signs for pedestrian and/or bicyclist crossings are comprised of a BICYCLE W11-1, PEDESTRIAN W11-2, or PEDESTRIAN and BICYCLE W11-15 sign and a DOWNWARD POINTED ARROW W16-7P supplemental warning plaque, erected at the crossing. In general, it is recommended to use W11-2 signs at sidewalk crossings where bicyclists are uncommon, W11-15 signs at shared use path crossings with both users, and W11-1 for crossings where pedestrians are uncommon. The arrow should point to the crossing in the road, with right-hand signs using an arrow pointing left and left-hand signs using an arrow pointing right.

While the OMUTCD shows TRAIL X-ING (W11-15P) as an optional plaque for the PEDESTRIAN and BICYCLE W11-15 sign, the DOWNWARD POINTED ARROW W16-7P plaque is required at trail crossings, as it communicates the crossing location.

Signs may be mounted on the far-side of the crosswalk approach to improve visibility between waiting pedestrians or bicyclists and approaching motorists. To add emphasis, a second set of crossing warning signage may be placed within a median (when present), or the left side of the road. This is a recommended practice on approaches with two or more approach lanes.

If there is insufficient intersection sight-distance (ISD) for motorists approaching the crossing, advance warning signage should be installed upstream of the crossing using the same warning sign type supplied at the crossing, supplemented by a plaque (W16-2P or -2aP) communicating the downstream distance to the crossing.

Yield Here to Pedestrians/Bicyclists Sign (R1-5)

At uncontrolled crossings where stop or yield lines are provided to denote the location where motorists should yield to pedestrians in a crossing, a YIELD HERE TO PEDESTRIAN sign may be used. If the yield condition includes bicyclists, a YIELD HERE TO BICYCLES AND PEDESTRIANS sign in black letters on a regulatory sign panel may be used.

While this sign may be used on single-lane approaches, they are recommended for use on all multi-lane approaches to encourage motorists to yield farther away from a crosswalk, improving visibility and reducing the risk of a multiple-threat crash. These signs are typically placed 20 to 50 ft. upstream of a crosswalk.

In-Street Crossing Signs (R1-6)

IN-STREET CROSSING Signs (R1-6) remind road users of state law regarding right of way at an unsignalized pedestrian crosswalks. Such signs should instruct vehicle operators to YIELD to pedestrians, and be placed on a centerline, lane line, or within a median. In-Street Crossing Signs are not to be post-mounted on the right or left side of the roadway.

When used on streets operating at or below 30 mph, the In-Street Pedestrian crossing sign (R1-6 series) can achieve motorist yielding rates between 60 and 90 percent. The R1-6 sign has also shown to be effective when deployed in a "gated" configuration on multi-lane streets, meaning a sign on the center line and additional signs located on each travel lane line.[7] These signs tend to require more frequent maintenance due to their in-street placement.

At locations where sight distance might be limited due to terrain or roadside visual clutter, the crossing may be enhanced with an OVERHEAD PEDESTRIAN CROSSING sign (R1-9 series). An R1-9 sign may be upgraded to an active beacon if supplemented with a flashing yellow light.

For more information, see OMUTCD Section 2B.12.

Turning Vehicles Yield to Pedestrians (R10-15)

TURNING VEHICLE YIELD TO PEDESTRIANS signs (R10-15) may be used to remind turning motorists of the right of way of pedestrians in a crosswalk.

While the R10-15 is listed as a sign to help regulate road users at signals (included under "Traffic Signal Signs" in the OMUTCD [Section 2B.53]), this sign may also be used at unsignalized locations providing the same regulatory reminder. Unlike other signs in Section 2B.53, the R10-15 does not reference signal indications or operations (i.e., "ON RED"). Further, the regulatory message is applicable to motorists on uncontrolled approaches who must yield to conflicting pedestrians who have the right of way when turning across their path.

Turning Vehicles Yield to Bicyclists

Where turning vehicles interface with bikeways at intersections, a TURNING VEHICLES YIELD TO BICYCLISTS sign in black letters on a regulatory sign panel may be installed to alert motorists of their requirement to yield to bicyclists within a crossing. In cases where motorists need to be alerted to a potential conflict with pedestrians and bicyclists, the sign should include both the words PEDESTRIANS and BICYCLISTS.

The sign can be located at the near or far-side of the intersection. Engineering judgment should be used to determine a location that is conspicuous to the turning motorist.

This sign may be used at controlled or uncontrolled crossing locations. Sign installation should be limited to the following:

- Crossings where turning motor vehicle volumes exceed 50 vehicles/hour;
- Locations where there is a documented history with drivers failing to yield;

- New installations of left side bicycle lanes or two-way bikeways where counterflow bicycle travel may be unexpected.

Blank-Out Signs

Blank-out signs are illuminated versions of static signs that may be active all of the time, or may be dark for specific conditions. They may be used in place of static warning or regulatory signs where it is desirable for the regulation or warning to be active a portion of the time. Where detection is used for sign activation, passive detection strategies may be preferable to requiring bicyclists to actuate a pushbutton. The use of advance detection may also be considered to ensure the blank out condition is activated prior to the arrival of a bicyclist. See Chapter 8.4.2 for further guidance related to bicycle detection for bicyclists. Common applications of blank out signs to improve bicycle and pedestrian safety include the following:

- Providing a temporary NO TURN ON RED restriction at a signalized intersection during protected pedestrian or bicycle phases;
- Providing a temporary or time-of-day-based turn restriction.

8.8.2. Bicycle Lane Signage

Bicycle Lane Regulatory Signs (R3-17)

The standard BIKE LANE (R3-17) sign may be placed along bike lanes, separated bike lanes, or bicycle-only paths to indicate the restricted nature of the bikeway to motorists, bicyclists, and pedestrians. These signs may be placed in advance of the start of the bikeway and at periodic intervals along a bikeway, as appropriate. Supplemental plaques indicating AHEAD and ENDS may be placed below the sign to communicate the start or end of a bikeway.

Intersection Lane Control Signs (R3-8 Series)

The R3-8 sign series include regulatory signs which communicates the presence and location of a preferential queue lane in advance of an intersection. While use of a bicycle symbol is not permitted on these signs, the text BIKE may be used on an R3-8 sign.

Begin Right (Left) Turn Lane, Yield to Bikes (R4-4)

The R4-4 sign is a regulatory sign which communicates the start of an auxiliary turn lane and reminds motorists of the presence of bicyclists and their obligation to yield to through bicyclists. While the sign does not mention bike lanes, it is only used where a bike lane is present. This sign should not be used to inform bicyclists and motorists of a weaving maneuver necessary when a through travel lane adjacent to the bike lane becomes a drop turn lane (see OMUTCD [Section 9B.05]).

Wrong Way Bicycling Sign (R5-1b)

Bicycle WRONG WAY signs may be installed as a countermeasure to discourage wrong-way bicycling within bike lanes and shared travel lanes. A supplemental RIDE WITH TRAFFIC (R9-3cP) plaque

may be added. This sign assembly can be mounted back-to-back with other roadway signs (such as parking signs) to reduce sign clutter and minimize visibility to other traffic. The RIDE WITH TRAFFIC plaque should be mounted immediately below the Bicycle WRONG WAY sign. Where used, the sign(s) face toward wrong-way bicyclists, placed on the left-hand side of a two-way street, or on one or both sides and facing away from traffic on one-way streets.

It may be difficult to discourage wrong way riding with regulatory signage alone, as this behavior can reflect a lack of wayfinding signs or insufficient bicycle network connections. If wrong way riding persists in the presence of this signage, consideration should be given to reevaluating the bicycle network to provide a suitable connection. One-way streets that have persistent wrong way bicycling may benefit from the conversion of the street to two-way operation for bicyclists.

Except Bicycles Plaque

For locations where warning or regulatory signs are not applicable to bicyclists, an EXCEPT BICYCLES plaque should be used to supplement the warning or regulatory sign. These plaques may be applicable to supplement a variety of signs, such as DO NOT ENTER, NO OUTLET, ONE WAY, RIGHT LANE MUST TURN RIGHT, etc. The R3-7bP version of the sign should only be used with other regulatory signs; the version with black letters on a warning sign panel should only be used with other warning signs.

Bicycles Merging Signs

For locations where a bicycle lane ends, it may be desirable to warn both bicyclists and motorists of the merge condition. This can be accomplished with a BICYCLES MERGE sign in black letters on a yellow warning sign panel, located at the point where a bicycle merging maneuver may occur. A supplemental W16-2aP plaque may be used to communicate the distance to the merge or end of bike lane. Either warning sign may be used in lieu of a BICYCLE BIKE LANE (R3-17) sign with supplemental ENDS plaque (R3-17bP). These warning signs should not be used where a bike lane drops in advance of intersection queue lanes and resumes immediately after the intersection.

8.8.3. Use of Custom Signs

Consistent with the OMUTCD, custom signs are permissible for situations in which provided signs do not convey information or instruction for road users. Such signs must be designed to OMUTCD standards. These include using appropriate shapes, colors, backgrounds, and legends consistent with the sign's function. The use of experimental symbols is prohibited.

8.9 Pavement Markings

8.9.1. Yield Lines

Yield lines consistent with OMUTCD Section 3B.16 may be used to indicate the point at which a bicyclist or motorist should yield in compliance with a YIELD sign or a YIELD HERE FOR PEDESTRIANS/ BICYCLES sign. Yield lines should comprise individual triangles with a base of 12

to 24 inches wide and a height equal to 1.5 times the base. The space between the triangles should be 3 to 12 inches wide. Yield lines may be desirable to emphasize the requirement to yield in advance of pedestrian or bicycle crossings at the following locations:

- Uncontrolled crossings;
- Exit legs of signalized crossings where motorists turn across a bicycle crossing during a concurrent phase;
- Motorist yield points at mixing zones (see Figure 6-32).

8.9.2. Green-Colored Pavement (Interim Approval)

Green-colored pavement may supplement other bikeway pavement markings to communicate to road users where portions of the roadway have been designated for exclusive or preferential use by bicyclists, and to enhance the conspicuity of a bicycle lane, bicycle lane extension, bicycle crossing, bicycle box, or two-stage bicycle turn box at or through an intersection. Ohio has statewide interim approval for the use of green-colored pavement (FHWA IA-14). Green colored pavement is an optional treatment that may be used by any jurisdiction within Ohio provided that each abide by the specific conditions for use as contained in the FHWA Interim Approval document and provide ODOT with a list of locations where the treatment has been installed. The use of green-colored pavement should be applied consistently throughout a bicycle network and can be used to improve the legibility of a bikeway network.

If green-colored pavement is not used throughout a bikeway network, it is recommended that it be used to guide bicyclists through transition areas between bikeway types and bikeway crossings to improve the legibility of the route.

Chapter 8 Endnotes

1 FHWA Tech Brief – "Safety Evaluation of Pedestrian Countdown Signals", FHWA Publication No. FHWA-HRT-19-046.

2 (2021) Cesme, B., P.G. Furth, R. Cashman, and K. Lee. **Development of pedestrian recall versus actuation guidelines for pedestrian crossings at signalized intersections**. Submitted to Transportation Research Record.

3 AASHTO Pedestrian Guide 2004, p. 103.

4 Thompson, Samson Ray Riley, "Bicyclist Compliance at Signalized Intersections" (2015). Portland State University, Dissertations and Theses. Paper 2222.

5 Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E. S. Park, J. Whitacre, N. Lalani, and D. Lord. *National Cooperative Highway Research Program Report 562: Improving Pedestrian Safety at Unsignalized Crossings*. NCHRP, Transportation Research Board, Washington, DC, 2006.

6 Shurbutt, J. and R. Van Houten. *Effects of Yellow Rectangular Rapid-Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalk*. FHWA-HRT-10-043. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2010.

7 Western Michigan University. *User Guide for R1-6 Gateway Treatment for Pedestrian Crossings*. Prepared for Michigan Department of Transportation, Lansing, MI, 2016.

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CHAPTER 9: MULTIMODAL ACCOMMODATIONS AT INTERCHANGES & ALTERNATIVE INTERSECTIONS

Chapter 9: Multimodal Accommodations at Interchanges & Alternative Intersections

9.1 General

This chapter focuses on pedestrian and bicyclist accommodations at interchanges and alternative intersections. This chapter expands on the general pedestrian facility guidance provided in Chapter 4, bicycle facility design guidance in Chapters 5 and 6, and motor vehicle facility design guidance in Chapter 7. Table 9-1 references the appropriate section in these chapters for design guidance at intersections.

Table 9-1: Cross Reference Table for Topics Mentioned in this Chapter

Chapter	Section	Content
Chapter 4 – Pedestrian Facilities	4.4 - Intersections and Crossings	Design of crossings, and treatments selection process, curb ramps, crosswalk markings
	4.5 - Other Considerations	Markings, signing, curb ramps and median islands, driveways, illumination
Chapter 5 – Shared Use Paths	5.6 - Shared Use Path Intersection Design	Restricting motor vehicles, speeds, curb ramps/aprons, widening, mid-block crossings
	5.7 - Signing and Marking	Signing and markings related to trail crossings and approaches
Chapter 6 – On-Road Bicycle Facilities	6.3 - On-Road Bicycle Facilities	Bicyclist facility types, including figures showing intersections
	6.4 - Evaluation of Uncontrolled Roadway Approaches to Bicycle Crossings	Countermeasures to provide crossing opportunities
	6.5 - Intersections and Bicycle crossings	Intersection pavement markings, general intersection design
Chapter 7 – Motor Vehicle Facilities Supporting Multimodal Accommodation	7.2 - Minimizing Turning Speeds at Intersections	Actual and effective corner radius, truck aprons, channelized islands
	7.8 – Speed and Volume Management	Mini-roundabouts; diagonal, median, and forced turn diverters

Designers should use this chapter to understand pedestrian and bicyclist safety and operations at interchanges and intersections but should consult the NCHRP 948 – Guide for Pedestrian and Bicyclist Safety at Alternative and Other Intersections and Interchanges (2021) for more in-depth analysis of these issues and considerations.

9.2 Design Principles and Objectives

Interchanges and alternative intersections are typically implemented to increase motor vehicle safety and capacity and reduce motorist delay by adjusting the geometric features, signal operations, or lane utilization and configurations of a more traditional intersection. As a tradeoff, pedestrian and bicycle routes through interchanges and alternative intersections often become more challenging. At interchanges, there are often multiple intersections to navigate which may be paired with free-flow vehicular movements, typically higher traffic volumes and vehicle speeds, and the presence of larger vehicles. While the route through the intersection or interchange may vary from a traditional intersection, it is still imperative to follow best practices for pedestrian and bicycle outlined in this guide. These practices include minimizing conflict points, crossing lengths, and motorist speeds, providing logical routes to be taken across the intersection, and providing adequate sight distances.

9.2.1. Principles of Accessibility

The same principles of accessibility apply to pedestrian facilities at interchanges and alternative intersections as at traditional intersections. See Chapter 4 for a review of accessibility.

9.2.2. Design Considerations

At the start of any intersection design, the following questions should be asked:

- Can pedestrians and/or bicyclists travel safely and comfortably through the intersection?
- Is it clear to pedestrians and bicyclists when and where to cross?
- Will pedestrians and bicyclists approaching and within the crossing location be visible to drivers?
- What is the volume and speed of vehicular traffic at the crossing?
- Are all pedestrian facilities and crossings accessible?
- Where pedestrian and bicycle facilities interact, are these users visible to each other?
- Is it intuitive for pedestrians to determine the direction of traffic at crossing locations?

In order to address these questions, designers should consider three components of pedestrian and bicyclist travel: traversing, wayfinding, and crossing. Overall, the design of these facilities should consider alignments that address user comfort and sight distances, minimize or eliminate multiple threat conditions, reduce motorist speeds at uncontrolled crossings, minimize the need for uncontrolled movements across crossing facilities, and provide appropriate buffer spaces between motorists and the non-motorized facilities.

Traversing

Traversing is the task of traveling through an interchange or intersection. It is important to develop a route that is as direct as possible and minimizes the number of crossings or the number of lanes crossed in a single movement. This is important because pedestrians and bicyclists desire to take the most direct route, or the route with least resistance, so the design should compel them to take the intended routes. Non-motorized users sometimes perceive large, complex intersections as too difficult to travel, and providing a complex route to navigate with multiple crossings further reinforces that negative perception. It is recommended that the designer balances the length of the route with the number of crossings.

Wayfinding

Wayfinding is the effort of identifying the intended route through an interchange or intersection. The more complex geometry of alternative intersections and interchanges can complicate wayfinding for nonmotorized users, especially for pedestrians with low or no vision. For all nonmotorized users, pedestrian and bicycle routes should provide adequate signage and striping. Wayfinding elements include signage, high-visibility crosswalks, colored pavement and striping to indicate dedicated space for bicyclists, directional markings to guide bicyclists to off-street facilities, detectable surfaces, lighting along the preferred route, buffer elements such as tree lawns when possible, raised elements such as curbs within median crossings to define boundaries and provide orientation elements, and accessible signals and pushbuttons.

Crossing

Crossing is the effort to cross the vehicular travel lanes in an alternative intersection or interchange. For pedestrians, it is critical to maintain an intuitive alignment through the crossing. Like wayfinding, this task can be more difficult for pedestrians with low or no vision. For bicyclists, crossing motorist lanes in an interchange or alternative intersection may involve additional striping to delineate specific locations for bicyclists to queue prior to crossing, or providing bicyclists with the opportunity to cross travel lanes before motorists enter the intersection. Since traffic may not approach from a typical direction it is also important to provide signage or cues for pedestrians and bicyclists at a crossing to alert them to what direction vehicles may be approaching from.

9.3 Interchanges

Specific design guidance for motor vehicles in interchange facilities can be found in the L&D Manual, Volume 1, Section 500.

9.3.1. Diamond Interchanges

Diamond interchanges are the most common form of interchanges. Diamond interchanges allow for free-flow operation on the major highway but create at-grade intersections on the minor roadway with the ramps. Intersection control within these intersections may include uncontrolled (free-flow), stop control, signalized control, and roundabout (yield) control.

Pedestrian Considerations

At a diamond interchange, designers should follow the same intersection design practices detailed in Chapter 4 and detailed earlier in Section 9.2. A benefit of diamond interchanges is that pedestrians only need to look in one direction for oncoming traffic when crossing interchange ramps.

With the ramp geometry mimicking a conventional intersection, designers should follow the recommended design guidance in Section 4.4 for pedestrian facility consideration and design.

Bicycle Considerations

At diamond interchanges, bicycle accommodations are generally similar to typical on-road bicycle facilities detailed in Chapter 6 of this manual. Care should be taken when designing bicycle facilities considering the speed of motorists and the lengths of turn lanes where bicyclists may be located between through and right-turning motor vehicles. It may be beneficial to provide opportunities to exit the on-road facilities to a side path where turn lanes are very long or encourage high speeds for motorists. Designers will need to make it visually clear where bicyclists are to remain in the roadway with enhanced striping and/or colored pavement to avoid trapping the bicyclist. Information on pavement markings in areas where bicyclists and motor vehicles may conflict with each other can be found in Section 6.5.

9.3.2. Cloverleaf Interchanges

Cloverleaf interchanges often utilize free-flow loop ramps to accommodate left-turn movements between the major and minor roadway. These free-flow ramps allow motorists to execute these left turn movements without traveling through an intersection and are often designed to allow drivers to navigate the interchange without stopping. Full cloverleaf interchanges use these loop ramps in all four quadrants while partial cloverleafs use loop ramps in one to three quadrants and diamond interchange intersection control options for the other quadrants. However, the use of high-speed free-flow ramps runs counter to the principles of safely accommodating pedestrians and bicyclists.

Free-flow ramps at cloverleaf interchanges often result in acute intersecting angles that limit visibility, permit drivers to accelerate or continue at a higher operating speed through the intersection, and orient vehicles so that drivers may not be pointed toward pedestrian crossings or looking in an opposite direction for oncoming traffic. These skewed crossings can increase the time that pedestrians and bicyclists are exposed to motor vehicles.

Limiting bicyclist exposure to motor vehicles at free-flow ramps can be challenging. The most complicated part of accommodating bicyclists is determining how to continue bicycle facilities through weaving areas where the ramp merges or diverges from the adjacent roadway.

Pedestrian Considerations

There are multiple treatments that can be implemented to help improve pedestrian facilities within the interchange. Designers should implement high visibility crosswalks and install pedestrian warning signage, yield lines, and potentially rectangular rapid flashing beacons at uncontrolled

crossings to warn drivers of the likely presence of pedestrians. Designers should also provide sidewalks through the interchange. Where adjacent land uses in the vicinity of the interchange are potential pedestrian generators, pedestrian facilities should be continuous along both sides of the interchange. Where it is determined that sidewalks should only be continuous along one sides of the interchange (e.g., to avoid a higher-volume, higher-speed free-flow ramps), designers should design the sidewalk network, approach roadways, and adjacent intersections to allow pedestrians to cross outside of the interchange area to the side where continuous sidewalk is provided.

Designers should consider treatments to slow traffic, improve sight distance, and encourage yielding to pedestrians in the intersection. By reducing speeds and improving sight distance, drivers have more time to react and yield to pedestrians waiting to cross or already crossing. Designing or reconstructing the on- and off-ramps from a free-flow condition to intersect the crossroad at an angle closer to 90 degrees with smaller radii reduces vehicular speeds and orients the driver to directly face the crossing location. If the control of ramps is modified, or the geometry of an interchange ramp is "squared up" closer to 90 degress, an Interchange Operations Study (IOS) or Interchange Modification Study (IMS) must be performed and coordinated with the Office of Roadway Engineering to confirm that the impacts are acceptable. See L&D Manual, Vol. 1, Section 550 for guidance.

Multi-lane right turns should be prohibited unless signalization is provided to eliminate the potential for the "multiple threat" scenario where one vehicle blocks the pedestrian from the sight line of a second approaching vehicle. Ensuring the crossing location is within the approach line of sight for drivers and meets stopping and intersection sight distance criteria is also critical to confirming pedestrians within the crossing are visible to approaching vehicles. Figure 9-1 illustrates some of these treatments for on-ramps, but similar treatments for lower-speed design can be used at off-ramps.

Bicycle Considerations

Providing clearly marked bicycle facilities through the free-flow merging and diverging areas at the ramp terminals is critical to improving visibility of the bicyclists and reducing exposure to vehicles exiting and entering the roadway. It is recommended that designers stripe entrance and exit ramps so through moving bicyclists do not have to weave across motorists and can continue traveling along the facility while turning motorists are required to yield (see Figure 9-1). This treatment is similar to the striping of on-street bicycle lanes at standard intersections where dedicated right turn movements are present to avoid a right-hook collision. It is also recommended to provide opportunities for bicyclists to leave on-street facilities and transition to a separated bike lane or shared use path. See Section 6.3.8 for guidance on transitioning bicyclists from on-street facilities to sidewalks to shared use paths. Figure 9-2 provides two striping and signing methods for accommodating bicyclists at exit ramps if the geometry of the ramp is unable to be designed closer to 90 degrees to the intersecting roadway.

Figure 9-1: Potential Bike and Pedestrian Treatments at Cloverleaf Interchange On-Ramps

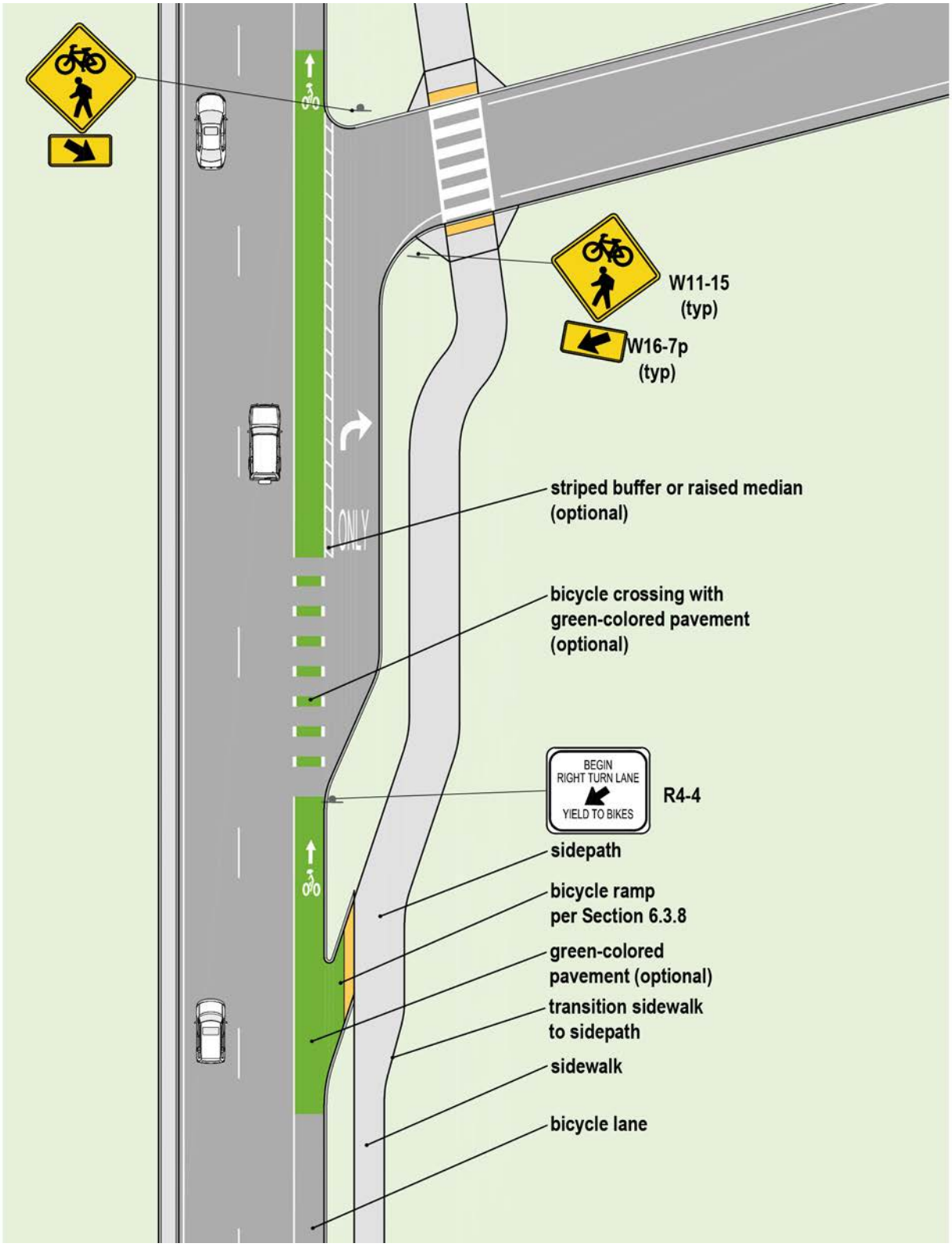
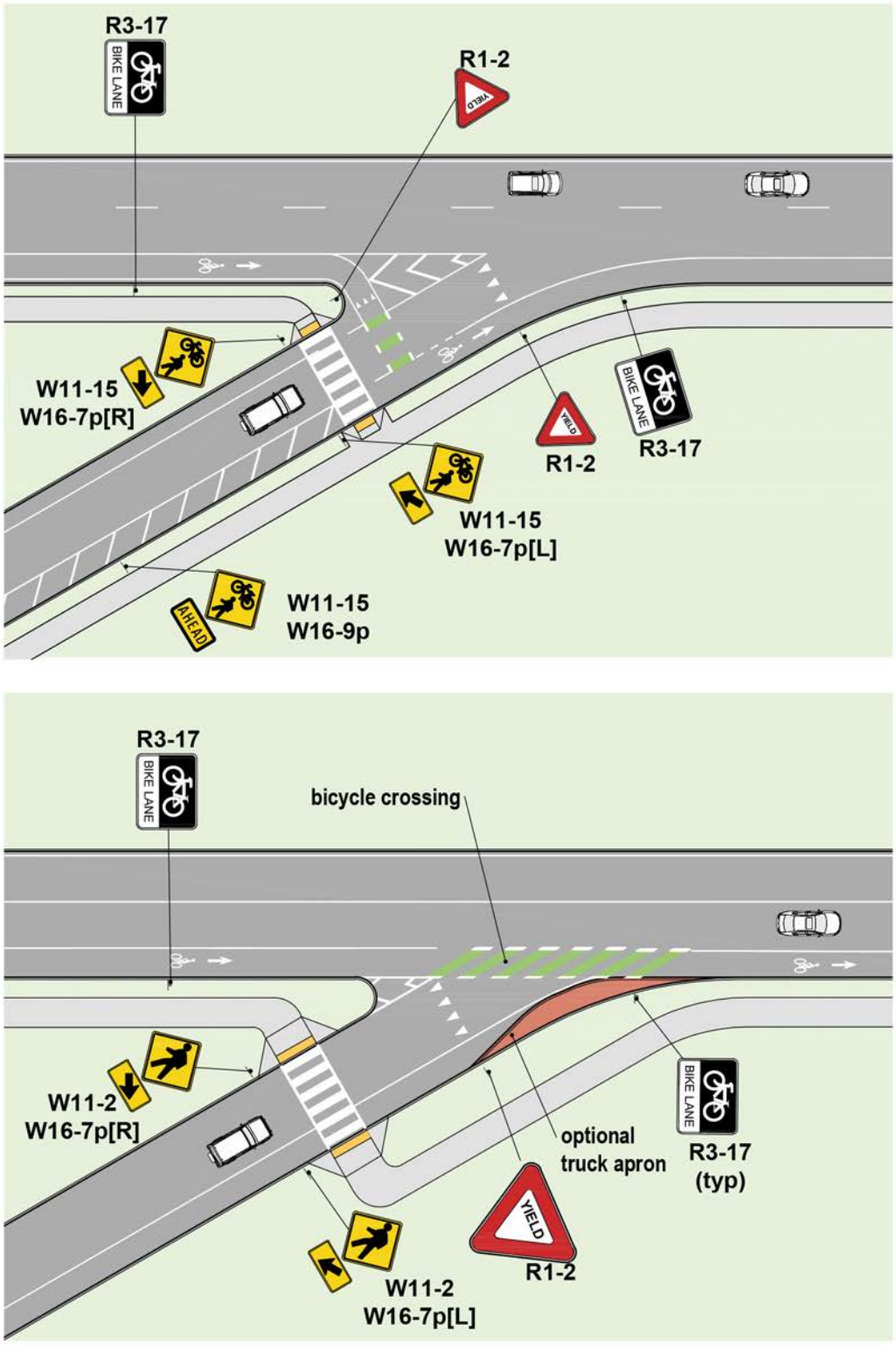


Figure 9-2: Bike and Pedestrian accommodations at free-flow exit ramps



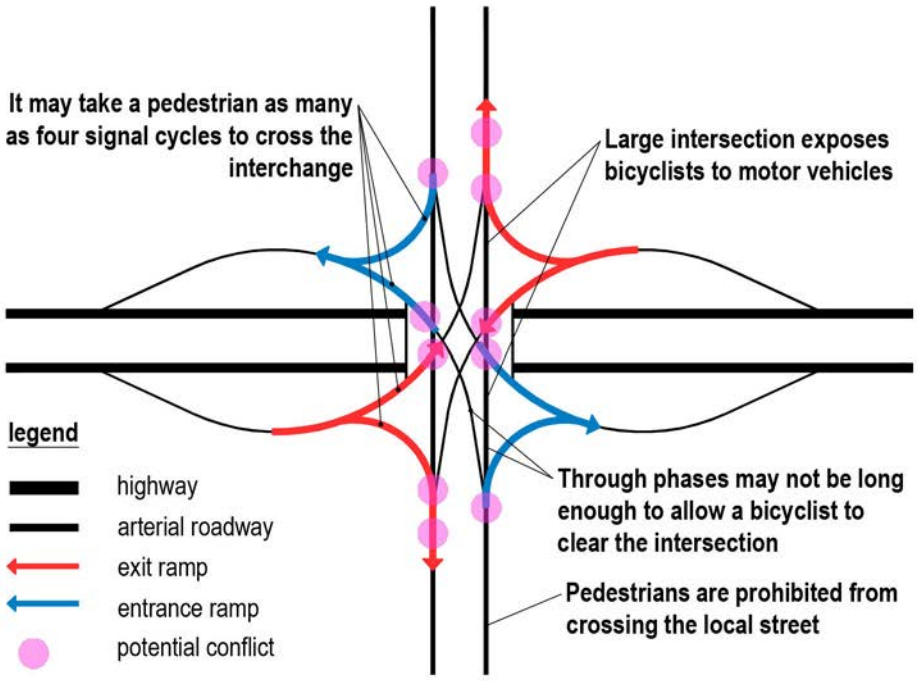
9.3.3. Single Point Urban Interchanges (SPUI)

A SPUI is a variation of a diamond interchange. L&D Manual, Volume 1, Section 501.2.1.2 provides design details for this type of interchange. The footprint of a SPUI is compressed to a single traffic signal, creating an "X"-pattern for vehicle traffic using the interchange ramps. With this interchange, right turn movements are often a free-flow maneuver to increase vehicular capacity and only the left turns pass through the traffic signal.

The biggest challenges to accommodating pedestrians at SPUIs stems from the sheer size of the interchange and resulting length of the pedestrian path of travel through the interchange, the number of conflicting signal phases, and uncontrolled crossing locations. Pedestrians are only able to cross a portion of the interchange in a single signal cycle and it might take as many as four phases to traverse the entire interchange if each crossing is signalized. Pedestrians may not desire the delay or additional effort to reach a crossing and may choose to cross outside of a crossing and signal phase, risking exposure to vehicles. Bicyclists face similar challenges to pedestrians when trying to navigate a SPUI. Due to the size of the intersection, bicyclists might have a difficult time clearing the intersection's yellow and all red phase. Uncontrolled right turn lanes may also expose bicyclists to large mixing zones and areas of increased conflict with higher-speed vehicles.

Figure 9-3 highlights the challenges that pedestrians and bicyclists face at a SPUI.

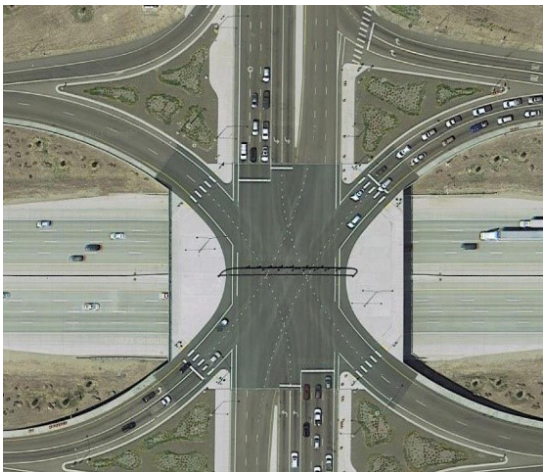
Figure 9-3: Bike and Pedestrian Facility Challenges at a SPUI


It may take a pedestrian as many as four signal cycles to cross the interchange
Large intersection exposes bicyclists to motor vehicles
legend
highway
arterial roadway
exit ramp
entrance ramp
potential conflict
Through phases may not be long enough to allow a bicyclist to clear the intersection
Pedestrians are prohibited from crossing the local street

Pedestrian Considerations

Options to address the challenges pedestrians face include providing a separated pedestrian facility (i.e., pedestrian bridge or underpass). This is the most expensive option, but it does reduce the chances for conflicts with vehicles and provides the clearest route for traversing the interchange. Other treatments include implementing high-visibility crosswalks and utilizing stop or signal control in lieu of free-flow right turn movements. Constructing crossings that intersect at 90 degrees will also help by reducing pedestrian crossing distances. Figure 9-4 shows a SPUI with pedestrian crossings with good alignment and high-visibility pavement markings.

Figure 9-4: SPUI with high-visibility and 90-degree pedestrian crossings (Source Google Maps)



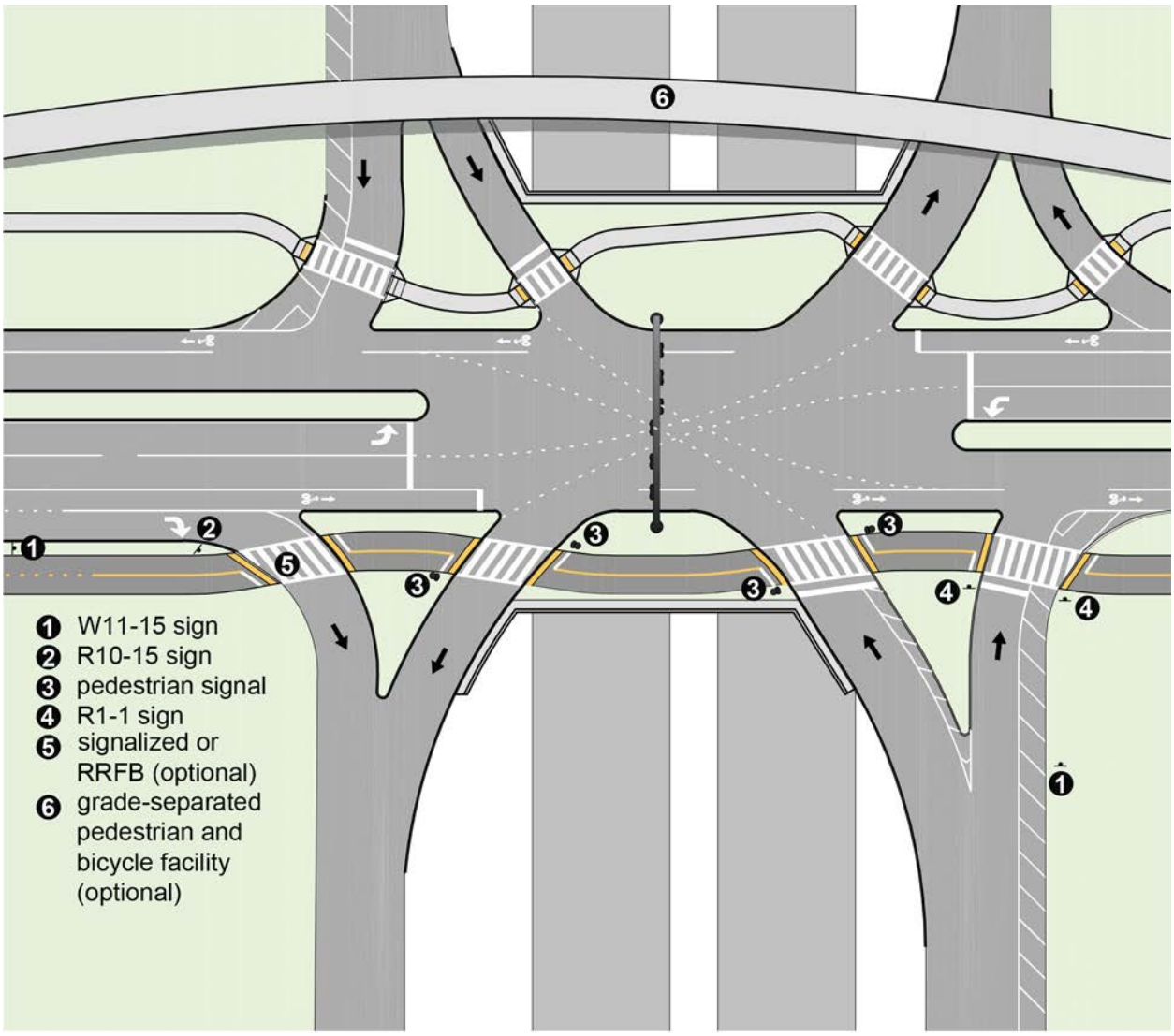
The designer will also need to consider how they route pedestrians through median islands within the interchange. These islands will be used as pedestrian crossing islands and should be designed as a comfortable and safe place for pedestrians to wait to cross. Channelizing elements such as curbing and low-height landscaping or barriers that do not block driver visibility can be considered to separate pedestrians from traffic and provide a clear pedestrian alignment through the islands. If an island is fully paved, curbing the pedestrian alignment or using different pavement textures may help pedestrians with vision disabilities better distinguish the pedestrian route.

Bicycle Considerations

Typically the volumes of motor vehicle traffic will provide sufficient minimum green time for bicyclists to cross the intersection. However, designers must ensure yellow and red clearance intervals are sufficient for bicyclists to cross the intersection (see Section 8.4.4). Providing a bicycle stop bar as close to the intersection as possible can help to reduce crossing distances. Putting the free-flow right turns under stop or signal control will help limit potential conflicts with vehicles since motorists will be forced to stop and check for bicyclists, pedestrians, and other motorists before completing their right turn. Reducing the number of free-flow right turns will also help to simplify the intersection and reduce potential bicyclist conflicts with motorists. Figure 9-5 illustrates various potential configurations for accommodating pedestrians and bicyclists at a SPUI.

If the control of ramps is modified, an IOS or IMS must be performed and coordinated with the Office of Roadway Engineering to confirm that the impacts are acceptable. See L&D Manual, Vol. 1, Section 550 for guidance.

Figure 9-5: Various Bicycle and Pedestrian Treatments at a SPUI


1 W11-15 sign
2 R10-15 sign
3 pedestrian signal
4 R1-1 sign
5 signalized or RRFB (optional)
6 grade-separated pedestrian and bicycle facility (optional)

9.3.4. Diverging Diamond Interchanges (DDI)

DDIs are a variation of the traditional diamond interchange. These interchanges use directional crossover intersections to shift traffic on the minor roadway to the left-hand side of the roadway between the ramp terminals within the limits of the interchange. The crossover eliminates the need for left turn signal phases for the ramp terminals, simplifying the motorist traffic operations and reducing vehicular congestion. L&D Manual, Volume 1, Section 501.2.1.4 provides detailed design information and criteria for DDIs.

There are several concerns for pedestrians at DDIs. The signal phases are different from a traditional signal and may be challenging to interpret for pedestrians, especially pedestrians with vision and cognitive impairments if they are unfamiliar with the interchange. Pedestrians may find the orientation of traffic approaching the crossing to be unexpected due to the shifting of vehicular traffic to the left-side within the interchange. Finally, like a Cloverleaf interchange, there are free-flow movements with geometry that could result in high vehicular speeds and skewed crossings that can be difficult to provide adequate sight distances for pedestrians to negotiate the crossing. However, DDIs may offer benefits to pedestrians over a traditional diamond interchange by reducing the number of pedestrian conflict points.

For on-road bicycle facilities, there are several areas of concern. As bicyclists move towards the signalized ramp intersections, the weaving condition at the entrance ramp diverge can create conflict areas between vehicles merging onto the entrance ramp and the bicyclists maintaining a straight route through the interchange area. This vehicular movement and the potential conflict is similar to a right turn at an intersection and requires consideration of the location and delineation of on-road bicycle facilities. Another area of concern is within the interchange core, between the signalized ramp intersections. On-road bicycle facilities remain on the right-hand side of the travel lanes through the interchange. This results in the bicyclists shifting from the outside edge of the roadway to the interior of the roadway. On narrower roadway footprints with the interior area constrained by piers (when the highway passes overhead) or with oncoming traffic buffered only by the oncoming bicycle lane, the comfort level of a bicycle lane can decrease.

Pedestrian Considerations

With a DDI configuration there is an opportunity to provide two different pedestrian routes through the interchange: through the center of the interchange in the median within the interchange core or along the outside of the interchange like traditional interchange configurations. Table 9-2 highlights the advantages and disadvantages of the two route placement options. Figure 9-6 and Figure 9-7 show examples of pedestrian routes traveling along the outside of the DDI and through the center of the DDI.

Table 9-2: DDI Pedestrian Path Location Comparison

Pedestrian Path along the Outside		Pedestrian Path through the Center	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Walkway doesn't conflict with center bridge piers at underpass locations	Need for a wider structure on the outside in overpass locations	Crossing of the arterial street is accommodated	Wait at center island dictated by length of signal phase for through traffic
Crossing one direction at a time	Cross free-flow right turns and free-flow left turns	Crossing one direction at a time	Cross free-flow right turns
Shorter crossing distances	Potential for additional right-of-way for underpass or construction of retaining wall under the bridge	Protected signalized crossing to the walkway	Might not know/ remember to look to the right when crossing to the center
Need for additional lighting for underpass locations	Need for additional lighting for underpass locations	Pedestrian delay to center is minimized by short cycles at two-phase signals	Pedestrian signals can conflict with vehicle signals at crossovers
Opportunity to use the right-of-way outside of the bridge piers at underpass locations	Providing signalized crossings requires more complicated timing and potential safety risks with queuing motorists	Pedestrian clearance time generally provided in crossover signal phasing	Out of direction travel for pedestrians not desiring to cross the arterial
Extension of the existing pedestrian network – more traditional look	Potential sight obstruction from bridge when crossing left turns	No exposure to free flowing left turns	Placement of facility in the middle of the interchange is counter to typical expectations
Typically able to view the path ahead.	Not sure what direction to look for vehicles when crossing turn lanes or the crossover	Protected signalized crossings to center walkway	Sidewalls must be managed to avoid sight distance impacts

Figure 9-6: DDI showing pedestrian facilities along the outside of the interchange
(Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)

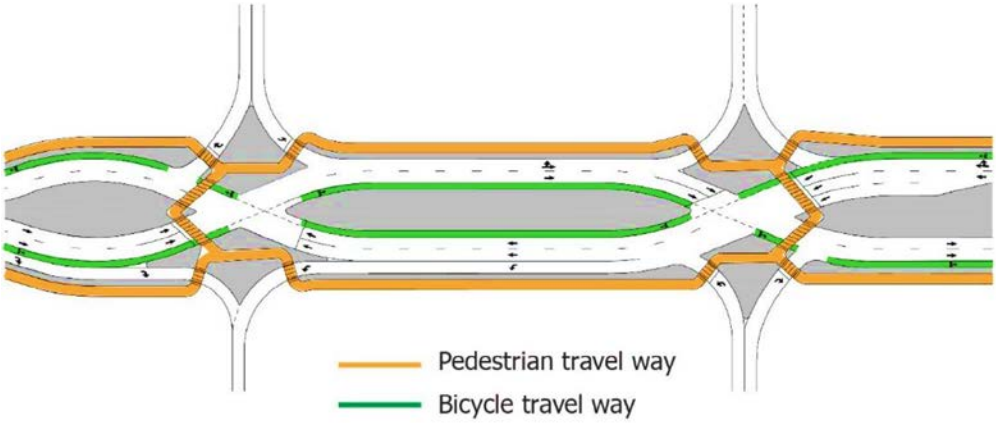
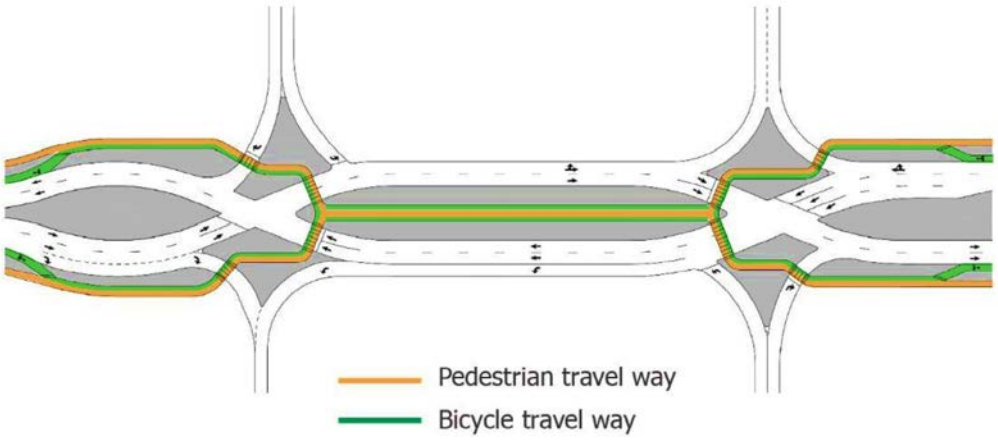


Figure 9-7: DDI showing pedestrian facilities through the center of the interchange
(Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Additional Pedestrian Crossing Considerations

When crossing the free-flow left turns and the walkway is along the outside of the interchange, place the crossing to allow for visibility between both the pedestrian and the motorist outside of the influence of bridge parapets, piers, or abutments. Crossing should not be placed too far upstream along the ramp where drivers are merging and may not be looking for a pedestrian as they are looking over their shoulder to find gaps in traffic coming from the free-flow off-ramp. Similarly, when crossing the free-flow on-ramp, place the crossing closer to the diverge point from the minor road at a point where vehicular speeds are reduced and where pedestrians are still easily in view for drivers that are looking ahead at the vehicles in front of them. When placing crossings, always ensure that the pedestrians can see the vehicles and that the drivers can see the pedestrians at each end of the crossing maneuver.

When crossing through the center of the interchange, designers need to provide a wide enough walkway for the pedestrian to feel comfortable, as they are often have barriers and moving traffic on both sides of them. Eight to 10 ft. is recommended to easily facilitate two-way pedestrian traffic and reduce the feeling of being trapped between barriers. When negotiating bridge piers that may be in the center of the roadway and within the sidewalk area, make sure the walk is wide enough to provide an adequate Pedestrian Access Route (PAR) to accommodate wheelchair access around the piers within the sidewalk limits.

When placing pedestrian signals and detectors near the median nose, provide adequate space for the crossing island for a pedestrian waiting to cross in one direction while providing space for the pedestrian crossing from the other direction to access the walkway. Splitting pedestrian signals and detectors of differing signal phases onto separate poles is preferable.

Drainage may also be a consideration when placing walkways within the median areas. Typically, the medians serve as a drainage area for the DDI. Designers must make sure the walkway properly drains when located within the median. Designers should provide a buffer between the walkway and roadway whenever feasible to provide space for drainage structures and to reduce the spray from motorists onto the walkway.

Bicycle Considerations

There are three options for accommodating bicyclists at DDIs: marked bike lane through the DDI, shared use path, or a shared travel lane. With all three of these options, signal timing should be timed to accommodate a bicyclist through all movements and phases.

Bike lanes should be designed with the guidance detailed in Chapter 6 of this document. Bike lanes should continue through the entire interchange. Wider bike lane widths adjacent to concrete barriers will be appropriate to address bicyclist shy spaces (see Section 3.6.2). Where bike lanes cross exit ramps, green colored pavement could be considered to indicate to motorists that bicyclists might be present and to help guide bicyclists through the intersection. Figure 9-6 shows bicycle lane placement on the right-side of vehicular traffic through a DDI.

There are also four scenarios the designer could encounter that will impact how bike lanes are treated approaching the interchange: no dedicated right turn entrance ramp lane, dedicated right turn lane, outside through lane becomes entrance ramp/turn lane, and multilane entrance ramps

- No Dedicated Right Turn Lane: The bike lane will stay to the right-side of the travel lane. This is similar to how bike lanes are treated at traditional intersections where no right turn lanes are present. See Figure 6-6.
- Dedicated Right Turn Lane: The bike lane will be located between the through and right turn lane similar to traditional intersections where dedicated turn lanes are present. See Figure 9-1.
- Outside Through Lane Becomes Right Turn Lane: When the outside through lane becomes the ramp/turn lane, the designer will have to transition the outside bike lane to the left side of this turn lane. See Figure 6-38.

- Multilane Ramps: Where multiple lanes exit from the minor street to the ramp, particularly if the inside lane is a through/right lane, the outside bike lane should use a bike ramp (see Section 6.3.8) to transition to a shared use path (or sidewalk) to cross the ramp with pedestrians. Another bike ramp should be provided to transition the bicyclist back to a bike lane once the multilane conflict(s) have been crossed.

Transitioning the bike lane to a shared use path is noted above as the preferred design for some of the options, but providing a bike ramp to a shared use path should be considered for any option where the bicyclist would otherwise be exposed to high-volume or high-speed motorist traffic. Shared use paths or separated bike lanes can be provided as the preferred bicyclist accommodations through the interchange. The configuration of these bikeways will follow the same alignment as the pedestrian routes described in the Pedestrian Considerations narrative above and illustrated in Table 9-2. These routes can be located through the center of the interchange in the median within the interchange or along the outside of the interchange like traditional interchange configurations.

It is important to consider the transition of the bicycle facilities from the approaching roadway to the interchange area if the facilities are different from those provided within the interchange. If on-street bike lanes are present approaching the interchange but separated facilities are provided within the DDI, the facility transition should occur at the nearest intersection prior to the interchange, but must occur at least 100 ft. prior to the interchange. For more guidance on bike ramps, see Section 6.3.8. Designers can also transition between different types of on-street facilities. For example, if a shared lane is used prior to the interchange, designers may transition to a bike lane or separated bike lane through the interchange. If possible, this transition should be made at an intersection prior to the interchange if located nearby, but must occur at least 100 ft. before the crossover intersection.

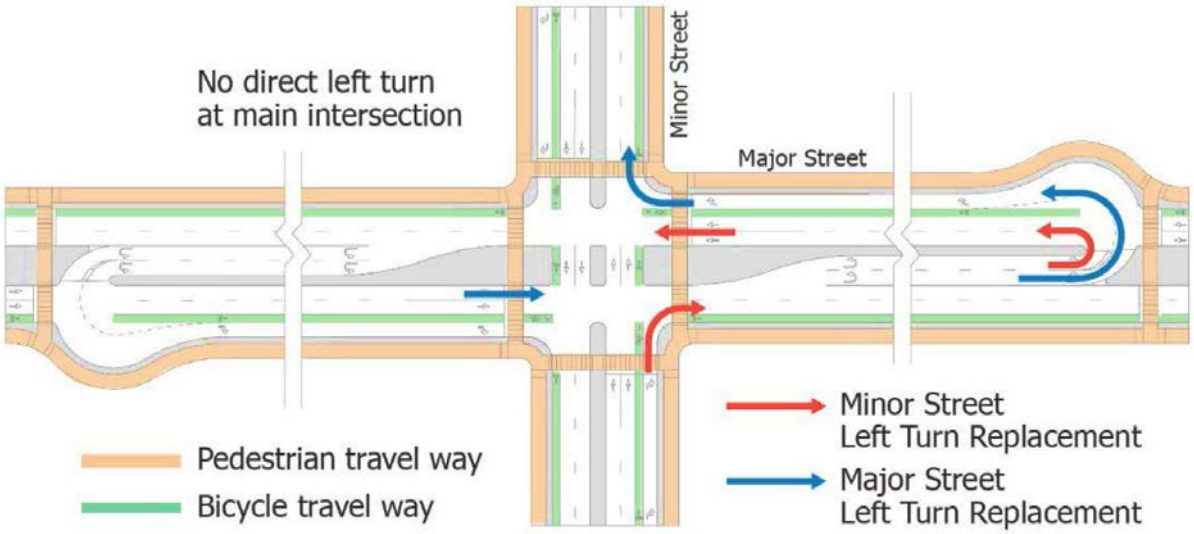
If bike lanes will not be provided, highly confident bicyclists may choose to ride in the traffic lanes with motorists. If posted speeds are 35mph or less, shared lane markings can be implemented through the interchange to reinforce to drivers that bicyclists are legal road users and that they might be present in the travel lane.

9.4 Alternative Intersections

9.4.1. Median U-Turn (MUT) Intersections

MUT intersections eliminate turns at the main intersection on one or both of the intersecting streets with indirect left turns using a U-turn movement located downstream from the intersection. Typically, a wide median is needed to provide separation between directions of traffic and facilitate the left turning movements. Vehicles on the minor street that would turn left at a conventional intersection will instead turn right onto the major street and then make the U-turn movement. Signals at the main intersection facilitate through and right turns. On the major street, signals can be provided at the U-turn movements if appropriate. Figure 9-8 depicts the typical turning movements for a MUT intersection.

Figure 9-8: Median U-Turn Intersection Layout (Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Pedestrian crossings within a MUT are similar to a traditional intersection. The differences between a MUT and a traditional intersection are a reduction in the number of conflict points between pedestrians and motor vehicles within the major intersection, and the opportunity to utilize the U-turn median area as a mid-block crossing location. Challenges for pedestrian crossings include potential delay for vehicles on minor roadways if the crossing distance is long and requires additional time for the pedestrian WALK signal, and exposure to right turn conflicts. Bicycle facilities traversing through the intersection operate similarly to traditional intersections. Since MUTs shift left turns outside of the major intersection the resulting U-turn movement becomes a right turn at the major intersection, resulting in a high volume of right turning vehicles. The increase in right turn volumes causes an increase in potential conflicts with bicyclists traveling through the intersection.

Pedestrian Considerations

There are several considerations designers need to make when designing pedestrian accommodations in MUTs. At the main intersection, the wide medians present the option for pedestrians to cross in either one-stage or two-stages, but one-stage crossings are preferred. A one-stage crossing reduces pedestrian delay and does not require pedestrians to wait in the median to complete the crossing. Two-stage crossings may be necessary where the width of the major street may result in poor signal operations if required pedestrian walk times are longer than the green time needed for the vehicular movements on the minor street. Figure 9-9 shows the difference between a two-stage and one-stage crossing. For a two-stage crossing, staggered crossings or other alignment changes are not recommended. Strategies to reduce crossings from two-stages to one-stage include:

- Increase the cycle length, allowing the pedestrian to cross in one cycle.
- Reduce median width to shorten the overall pedestrian route and reduce pedestrian clearance time.

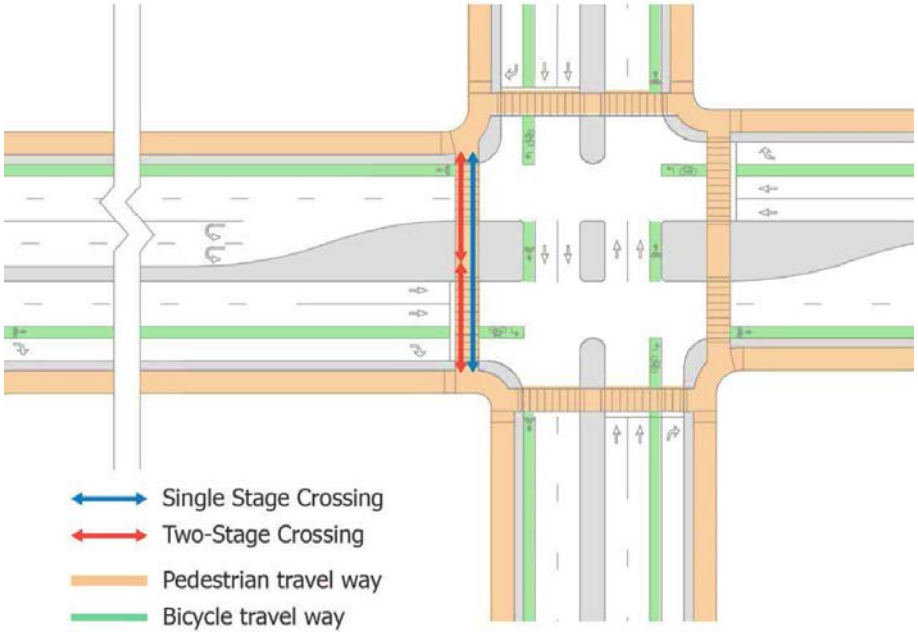
- Provide a pedestrian leading interval in the signal timing.
- Allow a pedestrian movement to alter signal phasing, which may temporarily alter signal coordination.
- Reduce the number of travel lanes or the widths of lanes and/or medians to reduce pedestrian clearance time.

Right turning movements and higher turning volumes at the main intersection also pose challenges to pedestrians. Designers should consider restricting right turns on red in order to increase safety and reduce potential conflicts between motorists and pedestrians. Designers should note, restricting right turns on red from the minor street may lead to increased conflicts with pedestrians crossing the major street. If the right turns use a channelized right-turn lane, pedestrian actuated signals or RRFBs may be used to bring attention to the presence of pedestrians.

The U-turn intersection is an additional opportunity to provide a signalized mid-block crossing. Typically MUTs only have signals that control that mainline traffic opposing the left turn as it approaches the U-turn intersection. By providing signals that control both directions of mainline traffic, a protected pedestrian crossing can be created.

For pedestrians with vision, mobility or cognitive disabilities, MUTs operate similarly to a traditional intersection. Providing clear delineation of the pedestrian route with curbing or landscaping can help facilitate navigation of the crossing. Developing a straight alignment between curb ramps from one area of the intersection to the next ensures pedestrians with disabilities can cross directly to a receiving curb ramp instead of wandering into the roadway, and it keeps the overall crossing distance to a minimum.

Figure 9-9: Crossing options at MUT intersection (Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Bicycle Considerations

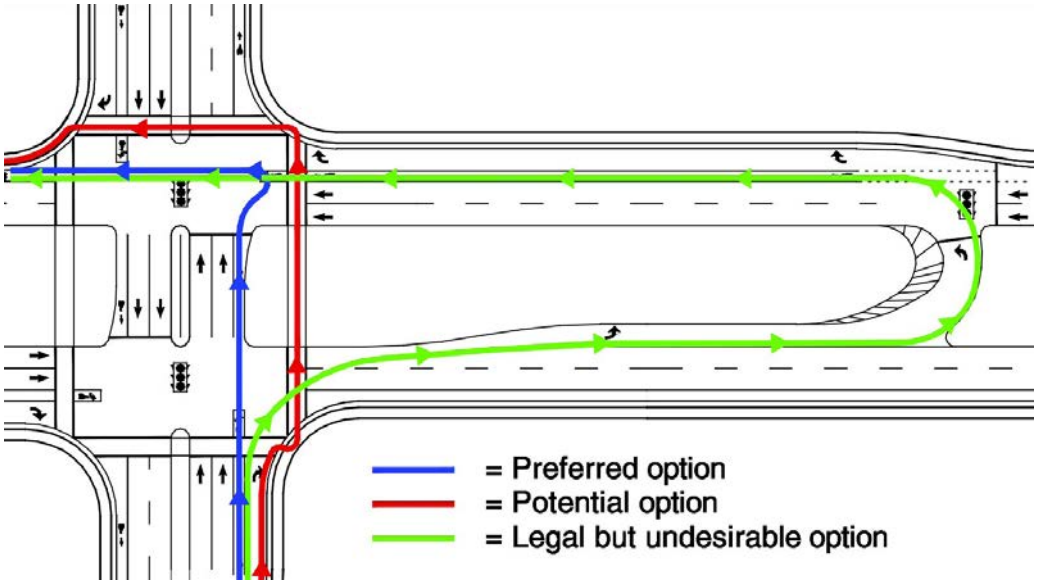
Bicyclists making through movements typically have conflicts with an increased number of right turning vehicles in this intersection configuration because motorists use the right turn to complete an indirect left turn from the major road. Designers need to consider the potential vehicle and bicyclist conflict between right turning vehicles and through bicyclists. There are several potential solutions to address this conflict.

- One potential solution is to transition bicyclists to a separated bike lane or shared use path prior to the start of any motorist right turn lanes to allow bicyclist movements to be phase separated from right-turning motorists.
- Another solution is placing the on-street bike lane to the left of a dedicated right turn lane, as illustrated in Figure 6-36. This layout still requires a weaving location for right turn vehicles to cross the bike lane. Colored pavement should be considered in this scenario to highlight the potential conflict zone between drivers and bicyclists.

Bicyclists executing a left turn movement from either the minor or major street should be accommodated using either a two-stage left turn (see Section 6.5.1) or by following the pedestrian path of travel. Although bicyclists can legally make the left turn movement as a vehicle using the U-turn, this movement presents out-of-direction travel and increased conflict areas that should be avoided. Figure 9-10 below illustrates each of these crossing alternatives from the minor to major street.

When specifying the use of shared use paths at MUTs, a bike ramp from the on-road facility to the shared use path is required. For guidance on bicycle ramps, see Section 6.3.8.

Figure 9-10: Left Turn options for bicycles (Source FHWA Median U-turn Intersection Informational Guide)



9.4.2. Restricted Crossing U-Turn (RCUT) Intersections

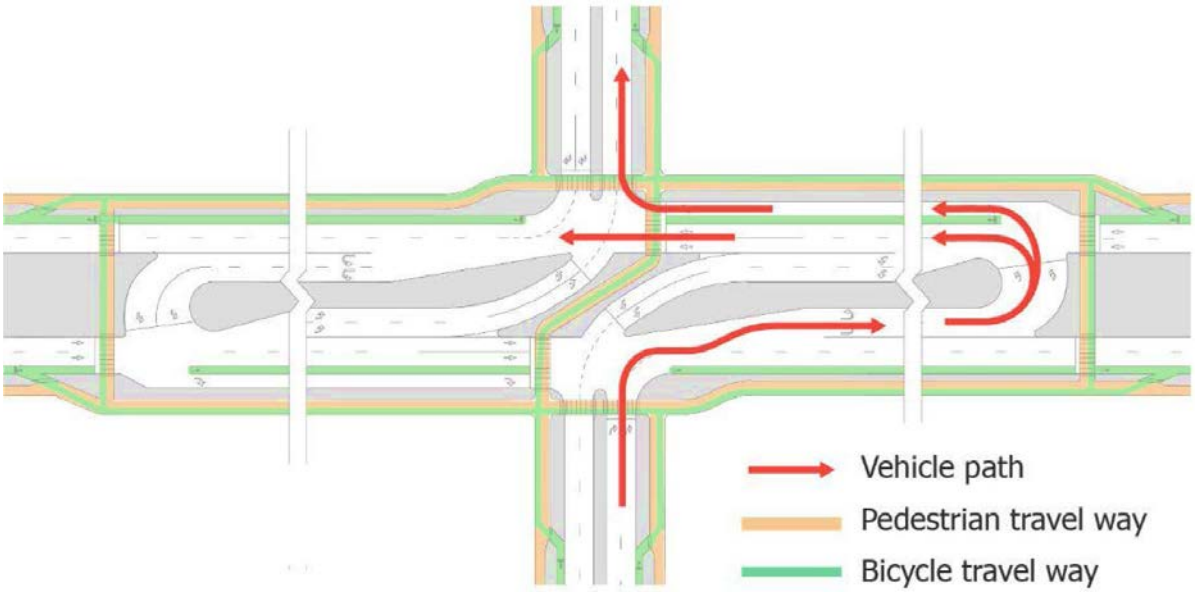
RCUT intersections eliminate left turn and through movements from cross street approaches at the intersection. To facilitate these cross-street movements, minor street drivers are required to turn right onto the major street and then make a U-turn maneuver at a one-way median opening downstream of the main intersection. Figure 9-11 illustrates the general movement of motorists navigating through and turning movements in the intersection.

RCUT intersections are typically considered on median-divided highways with heavy through and/or left turn volumes on a major street and low through and left turn volumes from a minor streets. RCUT intersections can have three or four approaches and can be signalized, stop controlled, or merge/yield controlled. Signalized RCUTs are typically part of a synchronized corridor while stop controlled RCUTs are usually at isolated intersections on four-lane divided arterials. Merge/yield controlled RCUTs are typically seen in rural high-speed corridors similar to freeway corridors.

For motorists, the benefit of an RCUT is improved safety through the reduction of conflict points between motor vehicles, increased efficiency since each direction of the main street can operate independently, and fewer signal phases which reduces delay.

For pedestrians, the RCUT's typical configuration differs substantially from crossings at traditional intersections. The "Z" crossing configuration (see Figure 9-12) results in out-of-direction travel, increasing pedestrian exposure and delay. The signal timing can also cause pedestrian delay by preventing a single stage crossing. Pedestrians with visual disabilities may also have difficultly discerning the movements through the intersection. Compared to a traditional intersection, RCUT intersections typically increase the volume of right-turning motorist, which can increase pedestrian exposure to turning vehicles.

Figure 9-11: Restricted Crossing U-Turn Intersection Layout
(Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Within a typical RCUT, bicyclists can travel either on a shared use path or within the roadway. With on-street facilities, bicycle left turn and through movements on the minor approach follow the same route as a vehicle through the U-turn to navigate the intersection. This movement is significantly different from a traditional intersection and requires multiple weaving maneuvers across vehicular lanes, increasing the number of conflict points between a bicyclist and vehicle, and increased out of direction travel. There are no clear routes for these movements from a minor street for bicyclists without modifying the RCUT design. Bicycle right turns can conflict with pedestrians and the high right-turn vehicular volumes. If channelized lanes are provided on any approach, there are increased conflicts related to the bicycle facilities crossing the channelized lanes.

Pedestrian Considerations

With the unique layout and motor vehicle movements in an RCUT, providing highly visible, clearly defined spaces for pedestrian crossings is critical to pedestrian safety and motorist recognition. Designers should consider the orientation of vehicles approaching pedestrian crossings to ensure sight lines are clear for the driver to easily see a pedestrian at the edge of the roadway waiting to cross and within the crosswalk itself.

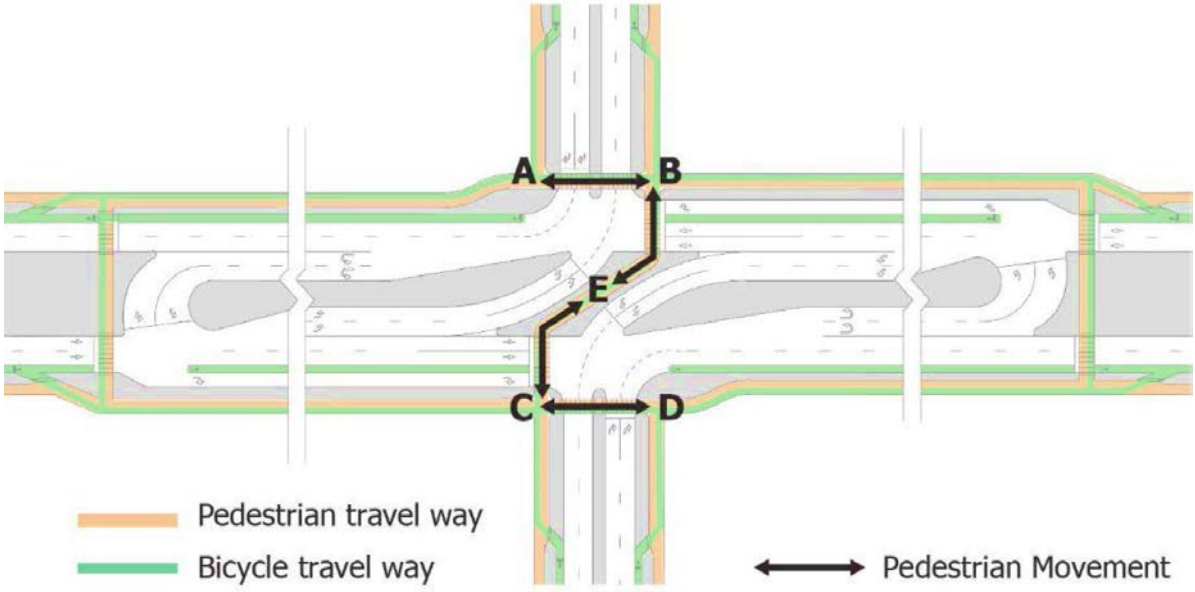
To overcome the wide geometric footprint that can impact pedestrian crossings, short cycle lengths can break-up the pedestrian crossing across individual directions of travel, creating crossings that are comparable to crossing times at traditional intersections. Designers will also need to ensure that crossings are accessible for all users, especially pedestrians with vision disabilities. Designers should include audible devices, channelization, and other techniques described earlier in this guide to delineate the pedestrian route and crossing.

With higher right turning volumes, it is recommended to control right-turn movements to protect pedestrians. If concurrent motorist/pedestrian movements are allowed, the curb radius should be as small as possible to reduce turning vehicle speeds and shorten the pedestrian crossing distance. If the right turn is designed as a channelized turn lane, the median island should be large enough for pedestrians to queue with geometry consistent with Section 7.2.6.

Wayfinding signing and other wayfinding devices will be critical to help direct pedestrians through the intersection. Other tools such as curbs and landscaping can be used to channelize pedestrians to the intended crossing locations.

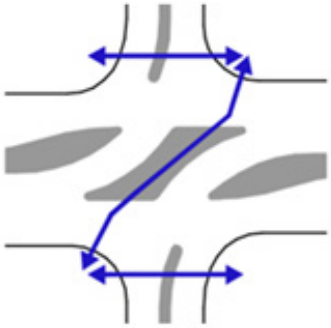
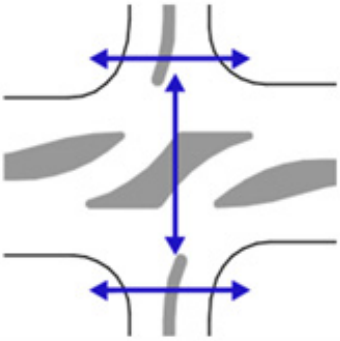
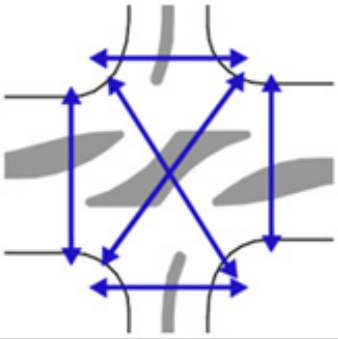
The “Z” crossing, shown in Figure 9-12, is a typical method for accommodating pedestrians at RCUT intersections. Pedestrians cross the minor streets in the same manner as a traditional intersection. However, when pedestrians cross the major street, they take a less traditional crossing through the median created by the opposing left turn lanes from the major street. This is a longer route than at a traditional intersection to cross from A to D, but a shorter route to cross between B and C. Natural pedestrian design lines should be considered based on adjacent land uses, transit stop locations, etc. to identify whether this pedestrian routing is appropriate for the expected pedestrian activity.

Figure 9-12: Pedestrian "Z" Crossing at RCUT Intersection
(Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Besides the "Z" crossing, pedestrians can cross RCUT intersections with a median crossing and a Barnes Dance. Table 9-3 depicts the various crossing options as well as the estimated travel time and delay pedestrians might experience. Mid-block crossings at the U-turn intersections should be considered at all RCUTs to supplement the main intersection crossings so that some pedestrians can avoid having to make the "Z" crossing. Median crossings are preferred at RCUT intersections with offset minor streets, but suitable pedestrian queuing areas need to be provided. A staggered crossing can also be implemented in the median depending on how offset the minor streets are from each other. For more guidance on staggered crossings, see Section 9.4.4. Another option at the main intersection of the RCUT is an exclusive pedestrian phase. As discussed in Section 8.3.4, exclusive pedestrian signal phasing can increase delay for both motorists and pedestrians and is only appropriate if the pedestrian volumes are significant.

Table 9-3: Crossing options at RCUT intersections (Source FHWA Restricted Crossing U-turn Informational Guide)

Crossing Type	Illustration	Mean Travel Time per Pedestrian (sec)	Mean Total Delay per Pedestrian (sec)
"Z"		465	132
Signalized Mid-block		479	119
Median Cross		487	160
Exclusive Pedestrian Phase		422	102

Bicycle Considerations

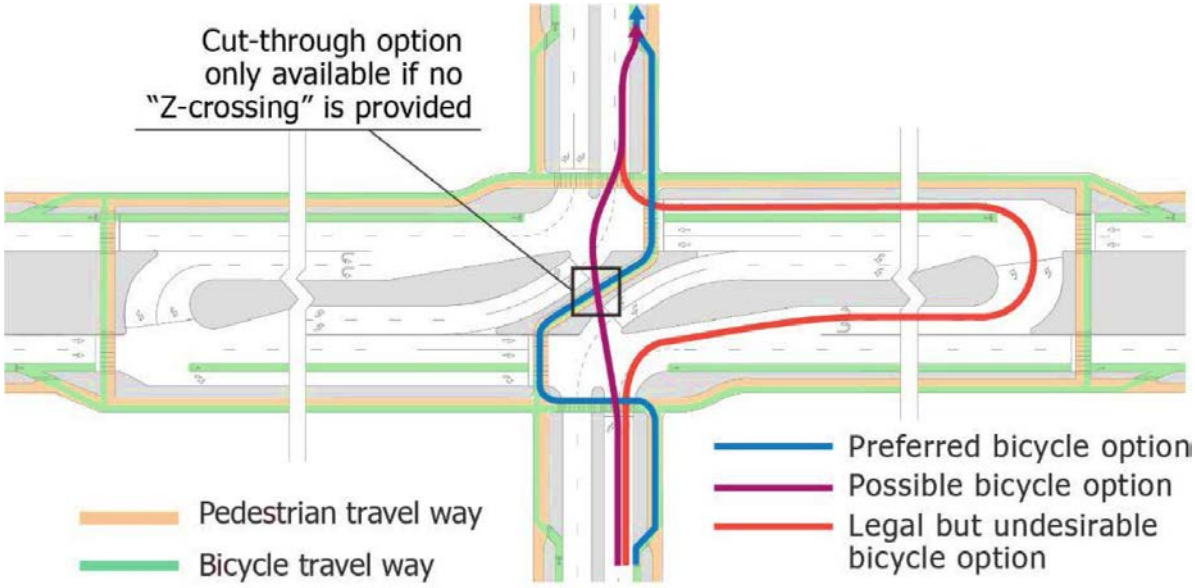
In an RCUT intersection, bicyclists can be accommodated in on-street bike lanes and shared use paths. Shared use path accommodations and crossings should be designed with the same considerations as typical pedestrian facilities. For on-street bicyclists the design will vary depending on if the bicyclist is on the major or minor street. In all cases, designers should consider providing bike ramps to allow on-street bicyclists to choose to exit on-street facilities prior to the intersection and return to on-street facilities after the intersection (see Section 6.3.8).

For bicyclists on the minor roadway, there are three ways to accommodate through and left turning movements as described below and depicted in Figure 9-13:

- Using a "Z" crossing (if provided).
- Using a more direct crossing route (if provided).
- Using a route similar to motor vehicles using the U-turn.

For bicyclists who choose to stay in on-street facilities on the major street, through and right turning users have a similar experience to traditional intersections, but typically have more green time to execute their maneuvers. For bicyclists on the major roadway wishing to turn left onto the minor street, the use of the "Z" crossing provides the most direct path of travel and should be accommodated. While Highly Confident Bicyclists might use the left turn lane with other vehicles, Interested but Concerned Bicyclists are more likely to exit at a pedestrian crossing and cross as a pedestrian. Finally, if the more direct crossing route discussed above is provided for the minor street, this crossing can also accommodate the left turn movement from the major street using a two-stage turn box located on the minor street. Wayfinding signing should be used to convey the available options to bicyclists.

Figure 9-13: Bicycle Crossing Options at an RCUT Intersection (Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)


Cut-through option only available if no "Z-crossing" is provided
Pedestrian travel way
Bicycle travel way
Preferred bicycle option
Possible bicycle option
Legal but undesirable bicycle option

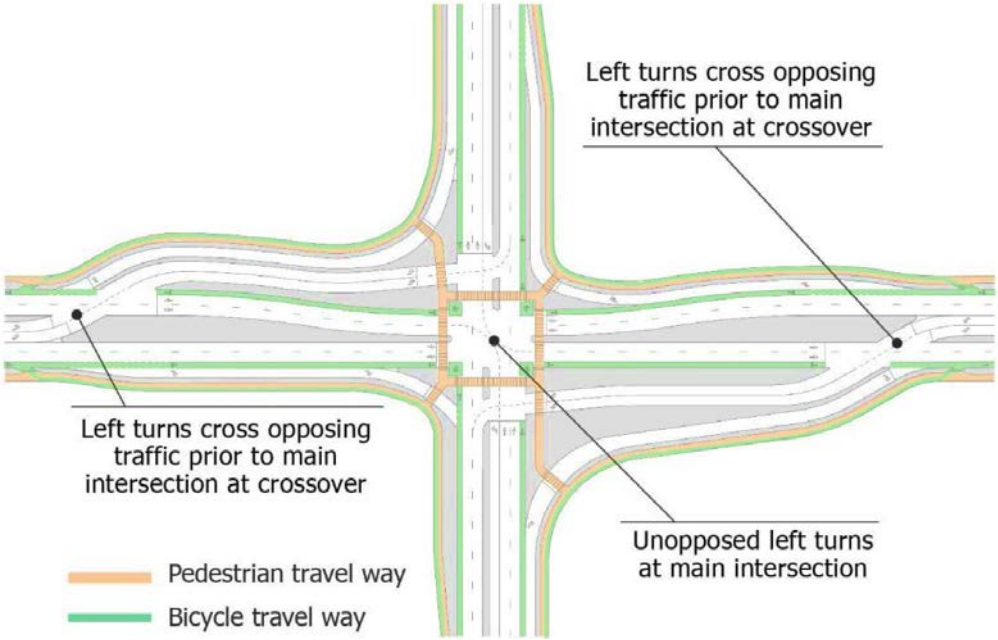
As with pedestrians, it is imperative to provide high visibility markings that can be easily seen by both bicyclists and motorist. The bicyclist's route through the intersection should be easy to follow and weaving areas between bicyclists and motorists clearly delineated so both road users are aware of the potential presence of each other.

9.4.3. Displaced Left Turn (DLT) Intersections

A DLT intersection, or a Continuous Flow Intersection (CFI), is an at-grade intersection that relocates left turns to the right side of opposing traffic with a crossover intersection upstream of the main intersection. By moving the lefts to the right side of opposing traffic, all movements on the major street can proceed simultaneously, eliminating the need for a separate left turn phase. Figure 9-14 below summarizes the vehicle movements at the intersection.

The goal of a DLT intersection is to reduce signal phases to reduce intersection delay for motorists and achieve higher vehicle capacity than a traditional intersection. However, this configuration and signal phasing creates tradeoffs for bicycle and pedestrian accommodations.

Figure 9-14: Displaced Left Turn Intersection Layout (Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)


Left turns cross opposing traffic prior to main intersection at crossover
Left turns cross opposing traffic prior to main intersection at crossover
Unopposed left turns at main intersection
Pedestrian travel way
Bicycle travel way

Pedestrian Considerations

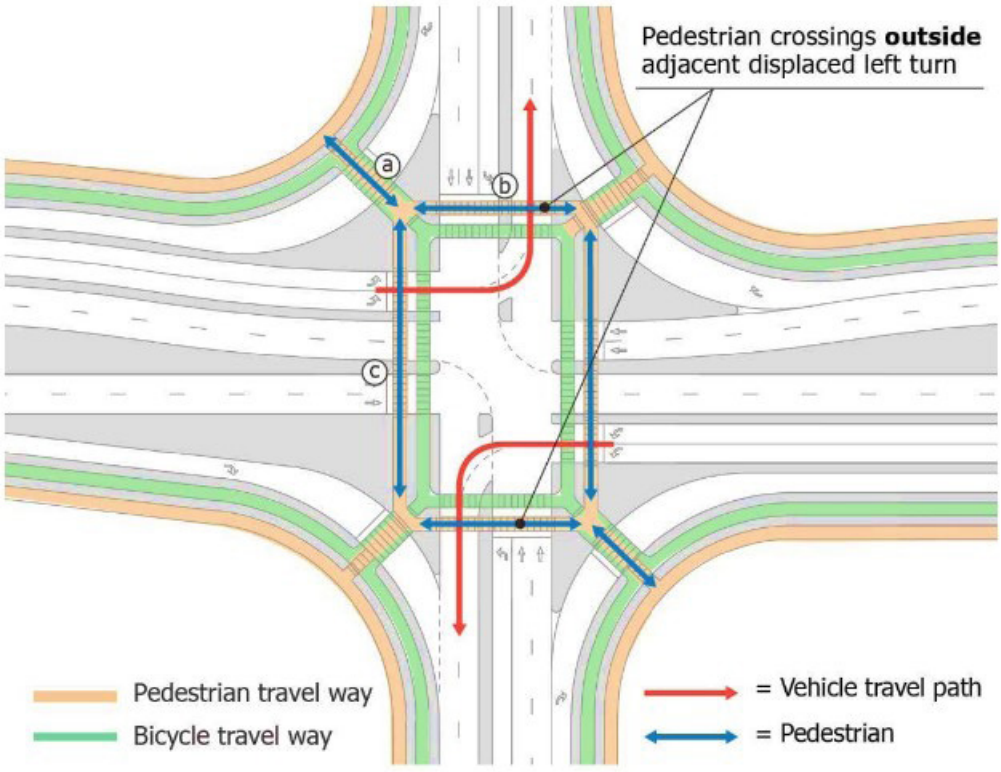
Pedestrian movements at DLTs are often significantly longer than at traditional intersections because they have to cross multiple vehicle lanes and medians. There are two typical crossing options for pedestrians at DLTs: an outside crossing or an inside crossing. Designers have the challenge of creating a reasonable route that minimizes travel time for pedestrians in both options.

Outside Crossing

For the "Outside Crossing," pedestrians cross the minor street on a route that is to the left of the displaced left turn movement for the major street. Figure 9-15 illustrates this type of crossing as movement "b."

There are several key elements to this crossing option. Pedestrians crossing the minor street are competing for green time with the displaced left turns from the major street. A leading or lagging turn phase could be implemented to avoid having pedestrians and the left turns cross at the same time. Designers should note that if there are dual-left turn lanes, a protected only left-turn phase would be required. When crossing the major street pedestrians may have vehicles approaching from the right in the nearest lane, which is an unexpected direction and may not be understood by pedestrians with vision or cognitive disabilities. The outside crossing can result in long crossing times and slower pedestrians may not be able to make the entire crossing in one cycle, making the crossing time even longer. For these reasons, the outside crossing is recommended when crossing lengths are relatively short.

Figure 9-15: DLT Outside Crossing (Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Inside Crossing

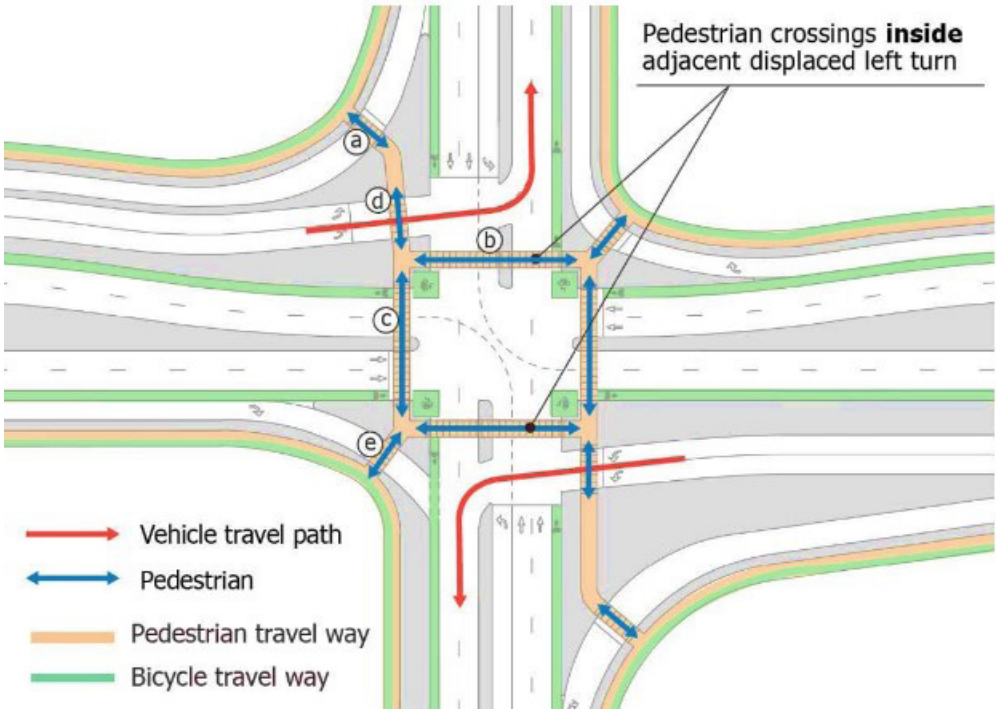
Inside crossings provide crossing islands that separate the displaced left turns from the major street through movements. Figure 9-16 illustrates this type of crossing as movement "b."

The inside crossings provide a shorter crossing distance from the main intersection; however, this approach may require multiple signal phases. These shorter crossings may benefit pedestrians, especially pedestrians with disabilities and slower walking speeds by providing more refuge locations.

In addition to deciding between inside and outside crossings, designers must consider the right-turn vehicle movements. Designers will determine if the right turns are signalized or not. If crossings are not signalized, designers must consider the method of traffic control, motorist speeds, and visibility to reduce the potential risk for pedestrians.

For both crossing options, channelization methods such as curbs, landscaping, and other methods previously mentioned should be used to direct and channelize pedestrians through the intersection. Due to the complex nature of the crossings, wayfinding signage should be provided.

Figure 9-16: Inside Crossing at DLT Intersection (Source NCHRP 948: Guidance to Improve Pedestrian and Bicyclist Safety at Alternative Intersections)



Bicycle Considerations

Designers have a few options for accommodating bicyclists at DLT intersections. For on-street bicyclists, an inside crossing with two-stage left turn bike boxes might be preferred. As shown in Figure 9-16, space is generally available to accommodate the bike box in front of the median that separates the displaced left-turning traffic from the through traffic on the major roadway. The outside crossing does not often provide a convenient or comfortable location for a two-stage left turn box between the through movement and the displaced left turn movement.

Bicyclists can also be accommodated on a shared use path and cross with pedestrians in both outside and inside crossing options as shown in Figure 9-15 and Figure 9-16.

Designers will also need to consider the bicyclist movements when determining cycle lengths for the intersection. Short cycle lengths that allow adequate clearance time are critical for bicyclists. Two-stage left turns or utilizing the pedestrian crossings can be subject to additional delay. Limiting delay will encourage bicyclists to use the facilities as intended. The large footprint of the intersection also means that the designer will need to ensure if the clearance interval is appropriate for bicyclists (see Section 8.4.4).

9.4.4. Roundabout Intersections

Roundabouts are generally circular shaped, yield controlled intersections that contain one or more circulating lanes around a central island traveling counter-clockwise. L&D Manual, Volume 1, Section 403 provides guidance on roundabouts. NCHRP Report 672 Roundabouts: An Informational Guide, Second Edition and the Manual on Uniform Traffic Control Devices also provide guidance on roundabouts.

With roundabouts, entering traffic yields to circulating traffic. The circulatory roadway geometry is designed to maintain low vehicular speeds, reducing crash severity for motorists in the intersection. A raised or painted splitter island is provided on all approaches to separate entering and exiting traffic. The curved geometry of the splitter islands aligns traffic with the circulatory road and promotes lower speeds for motorists entering and exiting the roundabout. Roundabouts are generally easier and safer for pedestrians and bicyclists to navigate because motorist speeds are low and the raised splitter islands create a two-stage crossing that allows pedestrians to focus on one direction of traffic at a time while also shortening the crossing length. Where fastest-path analysis shows that motor vehicles may be faster than desired for pedestrian conflicts, designers should consider adjusting the geometry, providing raised crosswalks, and/or provide truck aprons along the right-side of the rightmost lane to encourage slower speeds.

For pedestrians with vision disabilities, the circular geometry of a roundabout can present challenges as they may be unable to decipher the approaching vehicle from the circulating vehicles or know when vehicles have yielded. Bicycle facilities approaching a multilane roundabout also require consideration to provide bicyclists with alternatives to navigate the circulating roadway with minimal conflicts from motor vehicles. Given the challenges that multilane roundabout create for pedestrians and bicyclists, if traffic projections show that multilane roundabouts may be needed in the future, designers should consider constructing single lane roundabouts that would not preclude multilane construction if and when that additional capacity is needed.

Pedestrian Considerations

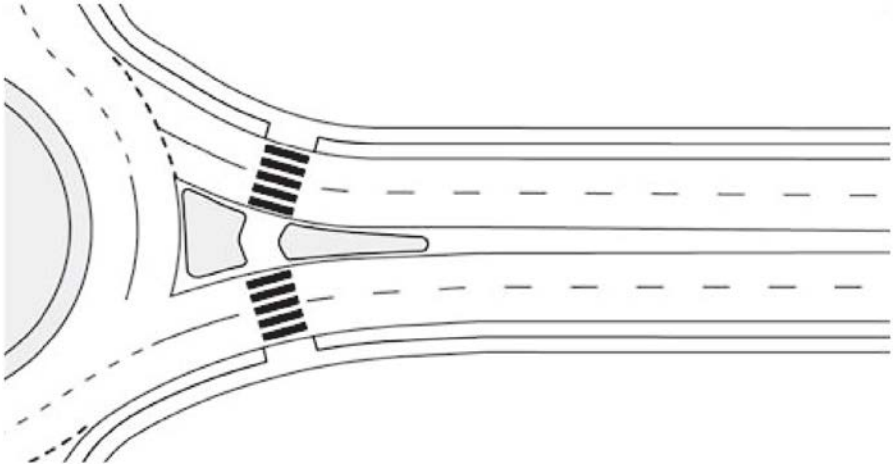
Compared to traditional intersections, roundabouts are generally easier and safer to traverse. Roundabouts break the pedestrian crossing into two stages, providing a refuge in the splitter island. While the navigation of a roundabout may be easier for many pedestrians, pedestrians with vision disabilities may struggle with the non-traditional layout of the roundabout. With a traditional intersection, the sound of a vehicle traveling through the intersection or making a right turn is distinct. Pedestrians with vision disabilities can generally distinguish the direction that approaching vehicles are coming from and how quickly or slowly vehicles may be approaching. With the circular geometry of the roundabout, vehicles passing the exit legs of a roundabout can sound like an approaching vehicle that then turns away. This variation in sound may be hard to distinguish from a vehicle that is actually exiting the roundabout if the pedestrian crossing is too close to the circulatory roadway. To overcome these concerns and to facilitate all pedestrian movements, designers need to ensure good channelization, proper alignment, and careful placement of the crossing.

The pedestrian crossing is typically placed 1 car length (20 ft.) back from the yield line on the entrance leg of the roundabout. This distance is far enough from the circulating roadway that pedestrians with vision disabilities can focus on the sounds of vehicles approaching or exiting the roundabout rather than the circulating traffic. The crossing should also be placed to maximize sight distances so motorists can see and stop before reaching the crossing when a pedestrian is present (follow the stopping sight distance criteria found in L&D Manual, Volume 1, Section 201.2). When developing the profile for the approach or exit of the roundabout, designers should take care not to place low points within the pedestrian crossing. Low points should be located at least 10-15 ft. away from the pedestrian crossing area to reduce the chances for water ponding or freezing in the pedestrian crossing.

The pedestrian route through the splitter island should be at least 6 ft. long and 5 ft. wide to serve as a pedestrian island. The longer and wider the crossing area, the more storage and pedestrian activity that can be accommodated. If bicyclists are expected to also use the crossing, the width should be at least 10 ft. wide and a length of 10 ft. should be considered to accommodate bicyclists with trailers. The pedestrian refuge through the splitter island should generally be at a similar elevation as the adjacent roadway, as opposed to ramping up and down with conventional curb ramps. The alignment of the pedestrian crossing can be designed three ways: straight, angled, and staggered.

- Angled crossings (see Figure 9-17) are the preferred configuration for pedestrian crossings, especially at higher volume roundabouts. The curb ramps are oriented perpendicular to the curbs, creating an alignment to the sidewalk that is more typical to a standard intersection and providing the shortest crossing distance. For multilane roundabouts, these crossings also better separate potential pedestrian pushbuttons in the splitter island. To help pedestrians better align with the crossing, the angle point within the splitter island should be well defined, as opposed to curved and subtle.
- Straight alignments (see Figure 9-18) typically keep pedestrians aligned in one direction through the entire crossing. This alignment results in longer crossing distances across the travel lanes

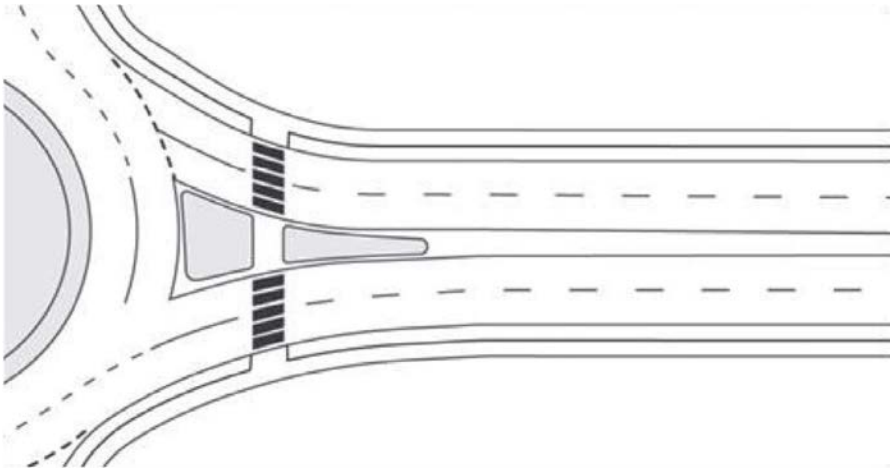
Figure 9-17: Angled Roundabout Crossing (Source NCHRP 834: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities)



and requires directional curb ramps (see Section 4.5.9). A straight crossing is also more likely to be treated by a pedestrian as a one-stage crossing (i.e., pedestrians may continue to cross without stopping in the pedestrian refuge.) This design should generally be avoided except in unique circumstances, such as compact roundabouts with narrow splitter islands where it may not be possible to provide a pedestrian refuge.

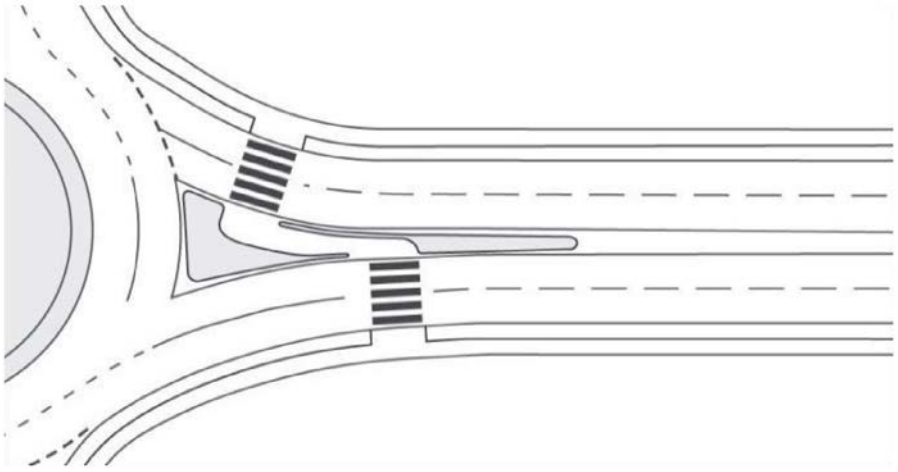
- Staggered crossing alignments (see Figure 9-19) have different offsets from the circulating roadway on the entry and exit lanes. The pedestrian refuge within the splitter island must

Figure 9-18: Straight Crossing at Roundabout (Source NCHRP 834: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities)



be designed with a minimum 5 ft. wide walkway that connects the two crossings, with wider widths necessary in areas of higher pedestrian volumes or where a shared use path is provided. Staggered crossings indicate to pedestrians that there are two separate stages to the pedestrian crossing. It also provides the most separation between pedestrian pushbuttons and signal heads if Pedestrian Hybrid Beacons are provided. It is recommended to offset the crossing on the exit leg farther from the circulatory roadway to allow for more vehicle storage, reduce the potential for vehicles queuing into the intersection, and provide more stopping distance for motorists to yield. Typically, the offset crossing of the exiting leg is placed 40 to 50 ft. from the circulating roadway. This separation from the circulatory road also benefits pedestrians with low or no vision as they can more easily decipher the sound of a vehicle exiting the roundabout from the circulatory roadway. Channelization with curbs or landscaping may be appropriate to discourage pedestrians from crossing at unexpected locations. These crossing applications are most appropriate at high volume, multilane roundabouts, especially where the splitter islands are wide and can easily accommodate the transitional area between the crossings.

Figure 9-19: Staggered Roundabout Crossing (Source NCHRP 834: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities)



Accommodating Pedestrians with Vision Disabilities

Visual cues are important factors for pedestrians navigating crossings at a roundabout. Pedestrians are tasked with looking for motorists yielding (or gaps in traffic) that will allow them to cross. This is much more difficult for pedestrians with visual disabilities due to free-flowing traffic and the absence of typical audible and tactile cues. Typically crossing a single lane roundabout does not present significant challenges, but multilane roundabouts are much more difficult to cross.

NCHRP Report 834: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities presents guidance for accommodating pedestrians with vision disabilities at roundabouts. To accommodate these pedestrians, enhanced facilities need to be constructed to create a crossing that is accessible. This report highlights facilities that may provide equivalent facilitation of crossings consistent with the draft PROWAG accessibility guidance for pedestrians with vision disabilities.

When considering multilane roundabouts as a design alternative, it is vitally important to consider how pedestrians of all abilities will be accommodated. Draft PROWAG R306.3.2 states that at multilane roundabouts, pedestrian crossings will require a pedestrian activated signal for each crossing stage, including in the splitter island. A pedestrian hybrid beacon (PHB) is an appropriate signalization treatment, however they are expensive and if overhead wayfinding signage is provided, a PHB can create additional visual clutter for motorists. Motor vehicle operations must also be a consideration when determining if a multilane roundabout with PHB's is an acceptable design solution and should be compared to the motorist operations if instead a single lane roundabout were provided. PHB warrants identified in the OMUTCD (Chapter 4F) should be followed when determining if a PHB is an appropriate signalization option for the pedestrian crossing. Multilane roundabouts that do not include accessible pedestrian signals should be designed to not preclude the ability to add them in the future.

Rectangular rapid flashing beacons (RRFB) with audible devices are not PROWAG compliant but do enhance accessibility. For additional information on using RRFBs at roundabouts to improve accessibility designers should refer to FHWA Publication No. FHWA-SA-15-069: Evaluation of Rectangular Rapid-Flashing Beacons (RRFBs) at Multilane Roundabouts. RRFBs are typically mounted on poles on the side of the roadway but can also be mounted overhead.

Additional non-signalized treatments can also be considered to improve accessibility. These treatments include raised crosswalks and speed tables to help reduce the speeds of motor vehicles at pedestrian crossings. Section 7.8.3 provides guidance on the design of speed tables and raised crosswalks. The orientation of these elements in a roundabout should center the pedestrian path on the curb ramp. See Table 9-4 for a summary of potential roundabout crossing enhancements discussed in this guide.

When designing raised crosswalks, the designer will need to consider the geometrics design and grade break alignment of the raised crosswalks, as well as other factors such as drainage impacts.

It is recommended to pair raised crosswalks with RRFBs to bring greater attention to pedestrians. Designers should work to reduce visual clutter and only provide necessary signage and markings to bring attention to the crossing. In addition to the design of the pedestrian crossing, designers also need to consider the sidewalk alignment within the intersection and leading to the crossing locations. When pedestrian accommodations at roundabouts are provided, it is recommended to provide a buffer between the sidewalk and the curb to help define the crossing locations.

The context of the project location, existing pedestrian accommodations, expected pedestrian activity, land use near the intersection, and community engagement should all factor into how pedestrians of all abilities are accommodated at multilane roundabouts.

Table 9-4: Roundabout Crossing Enhancements

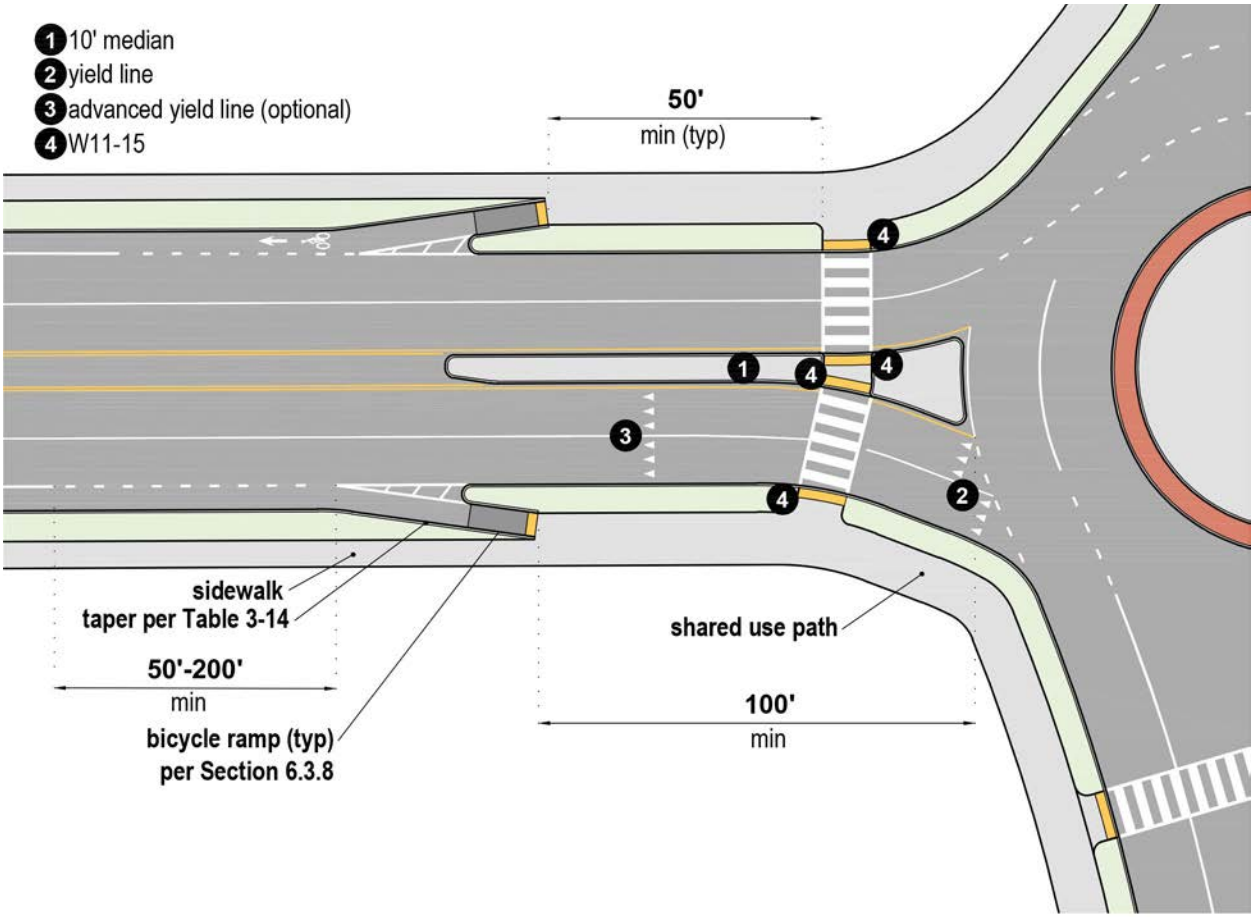
Crossing Treatment	When to Apply	Pro	Con
Raised Crosswalk/ Speed Table	At multilane crossings, crossings where designer wants to bring extra attention to pedestrians	Low cost	Difficulty to implement in a retrofit. Not preferred on routes with significant volumes of emergency services or trucks.
PHB	At multilane crossings	PROWAG compliant, enhance visibility of crossing. Less visual clutter at sides of roadway with overhead signal	High cost
RRFB	At multilane crossings, crossings at locations with heavy pedestrian generators such as school, parks, etc.	Low cost, enhance visibility of crossing	Can add to visual clutter on edges of roadway. Not PROWAG compliant.
Advanced Yield Markings	In advance of crossings	Identifies location for vehicles to stop prior to crossing. Highlights crossing location	Can add to visual clutter at intersection.

Bicycle Considerations

Typically, with single lane and compact roundabouts it is recommended to merge on-street bike facilities with motorist traffic so bicyclists travel through the roundabout in a shared lane. Additionally, the OMUTCD, Section 9C.04, states that bike lanes are not to be located within the circulatory roadway of a roundabout. While Highly Confident and Somewhat Confident Bicyclists may be comfortable traversing a roundabout in a shared lane environment, many bicyclists will not feel comfortable navigating roundabouts with higher motorist volumes, especially multilane roundabouts. For user comfort, roundabouts should also be designed to facilitate bicycle travel outside of the circular roadway on a separated bike lane or shared use path. Where shared lanes or bike lanes are provided on the approach to a multilane roundabout, it is recommended to transition on-street bicyclists to a separated facility.

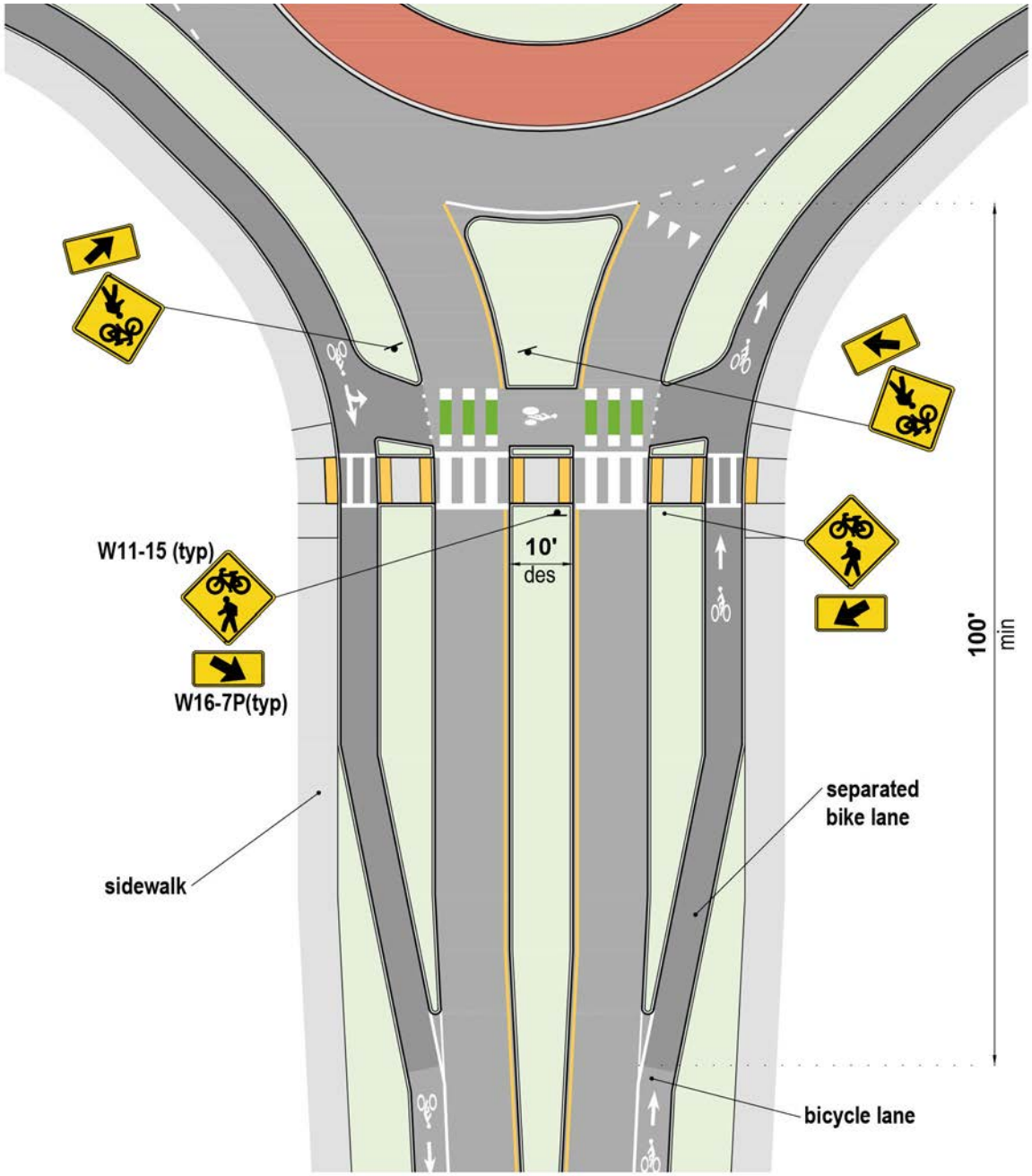
This transition from on-road to separated bikeway should be located a minimum of 100 ft. from the edge of the roundabout circulatory roadway (Figure 9-20). If on-street bike lanes are present, they should be terminated in advance of the roundabout at the transition to the separated bikeway. As shown on Figure 9-20, if the elevation of the separated bikeway differs from the on-road facility, a bicycle ramp must be provided to transition between these facility types. The bike lane line should be dotted for 50 to 200 ft. in advance of the taper to provide guidance to bicyclists who wish to travel the roundabout in the shared lane.

Figure 9-20: Bicycle Lane Transitions and Striping at a Multilane Roundabout



When separated bike lanes are provided on approaches to roundabouts, they may be continued around the intersection to maintain the continuity of the bikeway. When bike lanes are provided on approaches to roundabouts, and if it is desirable to maintain separation between bicyclists and pedestrians, the bike lanes may transition to separated bike lanes around the roundabout. Figure 9-21 provides an example of a separated bike lane at a single lane roundabout.

Figure 9-21: Bike Lane Transition to Separated Bike Lane at a Roundabout



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CHAPTER 10: TRANSIT FACILITIES

Chapter 10: Transit Facilities

10.1 Introduction

This chapter provides guidance for the design of bus transit related infrastructure – referred to as transit facilities. Transit facilities include the spaces that are required for boarding and alighting activity for transit passengers, infrastructure needed for bus vehicles to service the waiting areas, and reserved travel lanes for exclusive transit operation. The following areas of transit facility design are discussed in this chapter:

- Principles – key design principles governing the design of transit facilities.
- Accommodating Transit Users – guidance for access to bus stops, accessibility, and the design of the passenger waiting area.
- Bus Stop Treatments – guidance for the placement, configuration, and dimensions of various types of bus stops.
- Integrating Bicycle Facilities with Transit – guidance for transit stops adjacent to bicycle facilities.
- Bus-Only Lanes – guidance for bus-only lanes.
- Bus-Bike Lanes – guidance for lanes for the exclusive use of buses and bicycles.

The design of streets that include transit operations should be coordinated directly with the transit agency. The information provided in this chapter specifically addresses the design of infrastructure in jurisdictions where the relevant transit agency utilizes typical 40 ft. and 60 ft. buses. However, the designs discussed can be applied to other types of transit vehicles using the principles and considerations discussed in this chapter. Similarly, Bus Rapid Transit (BRT) systems often have system-specific requirements (e.g., higher transit platform heights, platform ticketing stations, real-time display boards, center-median platforms) that will be project specific and must be coordinated with the transit operator, but design principles presented in this chapter may still be applicable. Local agency guidelines should be used in jurisdictions where transit agencies have additional planning and design guidance for bus stops. This chapter does not discuss the design of light rail or trolley facilities.

10.2 Principles

10.2.1. Universal Design

Universal accessibility must be a priority for the design of transit facilities. Transit trips begin and end with either a pedestrian or bicycling journey and as such, design of bus stops and connections to bus stops must accommodate safe and comfortable facilities for people walking, using wheelchairs, mobility aids, bicycles, scooters, or other mobility devices. Placement of bus stop amenities, such as shelters and benches, require consideration of adjacent clear spaces for navigation.

Accessibility is discussed in detail in Chapter 4, but transit specific aspects are provided within this chapter.

10.2.2. Safety

Bus stop infrastructure should provide safe interactions for transit passengers and people walking, biking, and driving. Table 10-1 provides typical interactions at a bus stop and the design objective for protecting vulnerable users.

Table 10-1: Typical User Interactions at Bus Stops

Interaction	Design Objective
Transit Passengers Waiting at Bus Stop with Pedestrians/Bicyclists	Passenger waiting areas should be designed to reduce or eliminate interactions between transit passengers boarding or alighting and pedestrians/bicyclists traveling through the area. On corridors with bike lanes, the bus stop zone should be designed to reduce or eliminate the risk of bicyclist conflicts with buses.
Transit Passengers Waiting at Bus Stop with Transit Passengers On-board	Passenger waiting areas should be designed to be accessible and accommodate both the passengers waiting to alight and the passengers waiting to board.
Transit Passengers Waiting at Bus Stop Adjacent to Motor Vehicle Lanes	Stop amenities such as benches and shelters should be placed with appropriate buffers from the travel lane.
Transit Passengers On-Board with Vehicles	Pull-out bus stops must be designed for operators to safely decelerate and pull-in to the bus stop and merge back into traffic after serving the stop. In-lane and bus bulb stops should provide safe stopping zones for buses within the travel lane.

Design considerations and dimensions to help achieve the objectives listed above are discussed in Sections 10.3 - 10.6.

10.2.3. Comfort

The design of bus stops affects the level of comfort felt by bus passengers and street users traveling through the area. Table 10-2 identifies the areas of bus stop design that affect comfort.

Table 10-2: Factors Affecting Comfort

Factors Affecting Comfort	Description
Shared spaces	Sharing waiting space with pedestrians or people biking means that bus passengers must be aware of approaching users and potentially move to allow them to pass. Designated space for transit access and waiting, separate from other uses, offers peace-of-mind for waiting passengers.
Stop amenities provided	A comfortable waiting experience can be provided by offering a place to rest, to shelter from weather conditions, to see and to be seen with appropriate lighting, etc.

10.3 Accommodating Transit Users

10.3.1. Pedestrian Access to Transit Stops

The portion of the transit journey between the start or end and the bus stop is just as important as the experience at the bus stop or on board the transit vehicle. Municipalities and transit agencies should work together to ensure that the pedestrian infrastructure in the area around each bus stop is sufficient for safe and comfortable access. Accessible paths should be available from all directions to the bus stop. Design guidance for pedestrian accessibility can be found in Chapter 4. The bus stop waiting area should be separated from the Pedestrian Through Zone to maintain accessibility for people waiting at the stop and traveling along the sidewalk.

At intersections with bus stops, safe pedestrian crossings must be provided for passengers crossing to and from bus stops on the other side of the street. Where mid-block bus stops are provided, appropriate pedestrian crossings help to ensure that pedestrians do not risk making unsafe crossings. See Section 4.4 for pedestrian crossing guidance.

10.3.2. Bicycle Access to Transit Stops

Safe and continuous bicycle facilities can effectively widen the catchment area of transit stops and can support transit trips that begin or end by bike. Some people who access transit by bicycle will need to lock their bikes at the transit stop, while others will bring their bike with them on the transit vehicle. Where access to transit is expected by bicycle, bike racks and/or bikeshare stations should be considered at or near the transit stop, and transit agencies should work to accommodate bikes on buses (see Section 6.3.9).

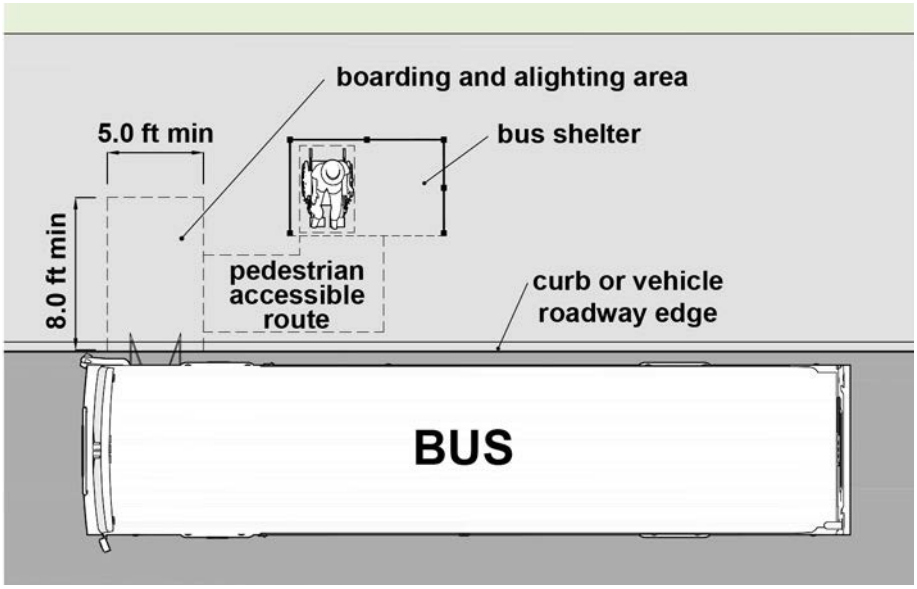
10.3.3. Bus Boarding and Alighting Area Accessibility

An accessible boarding and alighting area is required at every bus stop. Section R308 of PROWAG identifies the dimensions required for pedestrian access and maneuverability at bus stops with a specific focus on people in wheelchairs and using accessibility devices.

An 8 ft. by 5 ft. space is required for transit rider boarding and alighting (see Figure 10-1). This space accommodates the deployment of a ramp from the transit vehicle and the space needed for a pedestrian to access the deployed ramp. If necessary, this boarding and alighting space can overlap with other spaces such as the Pedestrian Through Zone. The 8 ft. x 5 ft. space is required at the accessible boarding and alighting door of the transit vehicle; however, many transit vehicles have more than one door, and different vehicles may have different door spacing and operations (i.e., rear door loading vs front door loading). The different vehicles using the transit stop should be considered when locating and designing the accessible boarding and alighting area, but a firm and stable surface should be provided to accommodate access from all doors of the transit vehicle(s).

The preferred grade of the boarding and alighting area is 1.56 percent (2.0 percent max) perpendicular to the curb. Parallel to the curb the grade should match the grade of the roadway to the extent practicable, though 1.56 percent is preferable to serve as a suitable turning area for people in wheelchairs. Additional pedestrian accessibility guidance is provided in Chapter 4.

Figure 10-1: Passenger Boarding and Alighting Area and Accessible Connections



An accessible connection must also be provided between the pedestrian waiting area and the boarding and alighting area (Section 10.3.4). Figure 10-1 illustrates a passenger waiting area with a transit shelter that has been sized so that an accessible route is provided between both areas.

10.3.4. Passenger Waiting Area

The passenger waiting area is designated for people waiting to board and alight transit vehicles. This space can include shelters, benches, lighting, and other street furniture. Passenger waiting areas are typically situated within the following zones depending on the type of roadway:

Street designs should clearly separate transit passengers from vehicles in travel lanes and provide a comfortable area for waiting and accessing the boarding and alighting area.

The passenger waiting area design must meet accessibility guidelines, and the provided amenities should be based on the land use context, the frequency of transit service, the passenger demand at the stop, and desired facilities. Stops in more densely populated areas, with greater frequency and volume of use, and at major destinations are likely to need a larger footprint to accommodate

Table 10-3: Typical Location of Bus Stop Waiting Areas

Roadway Type	Location within Cross-section
Curbed Roadways	Buffer zone – the space between the curb and the Pedestrian Through Zone often accommodates the waiting area and stop amenities. In some constrained areas, the bus stop waiting area may be located along the back of the sidewalk behind the Pedestrian Through Zone.
Uncurbed Roadways	Shoulder area – the space starting at the edge of the travel lane is used as a bus stop and space beyond the edge of shoulder may serve as a passenger waiting area.

the desired amenities, whereas stops that are used less frequently might only meet the basic requirements. The following sections provide considerations for some common context types.

The preferred grade of the waiting area should be 1.56 percent (2.0 percent max) perpendicular to the curb. Along the roadway, the grade of the roadway can be used to the extent practicable.

Frequent Bus Stop

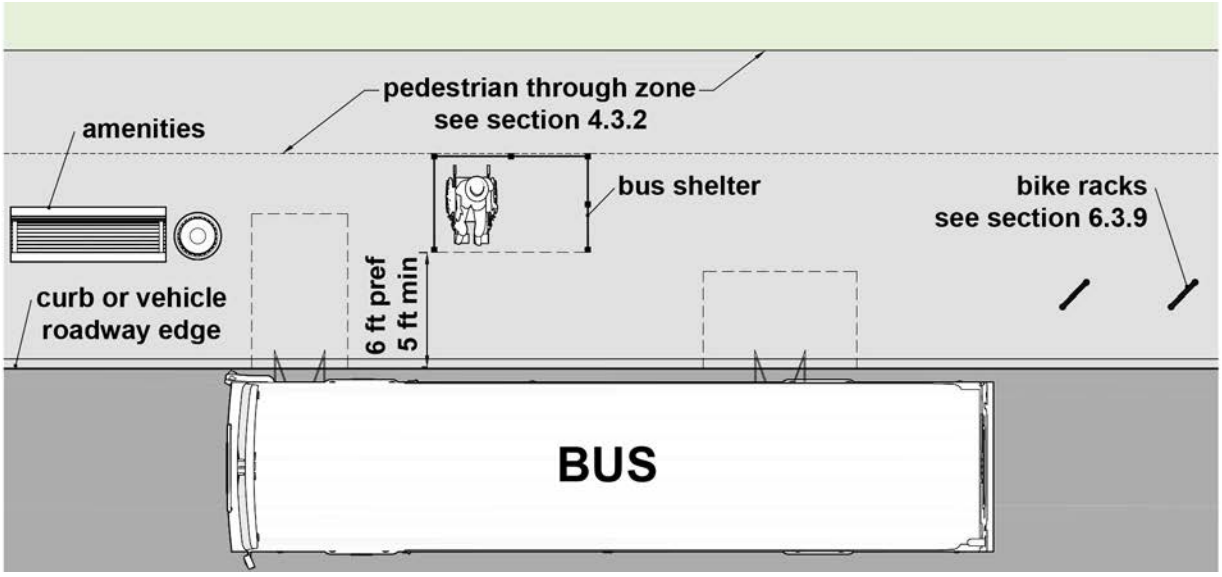
Wide Pedestrian Zone

In contexts with increased pedestrian activity and frequently used bus stops, the Pedestrian Through Zone and passenger waiting areas should be separated as much as possible and maximized in dimensions. This context is typically encountered in urban business districts or within town centers of municipalities. This type of stop may also be used in contexts with major activity centers such as schools, community centers, or health facilities. Where the pedestrian zone available is wider than 12-15 ft., the passenger waiting area can be placed in the buffer space in between the curb and the Pedestrian Through Zone.

A passenger waiting area that is 10 ft. wide perpendicular to the curb can accommodate a 4 ft. deep shelter facing towards the curb and a 6 ft. buffer in between the shelter and curb. A 5 ft. buffer is the minimum needed to accommodate the pedestrian access route and an ADA accessible turning space. The design should ensure that at least 5 ft. of space is also provided behind the shelter (waiting area) to accommodate the Pedestrian Through Zone, although wider is preferred given the context and higher pedestrian volumes (see Section 4.3.2).

A passenger waiting area that is 8 ft. wide perpendicular to the curb can accommodate the minimum requirements for the boarding and alighting area at the accessible transit door. A shelter can be accommodated if it either faces away from the curb or if it uses shelters with either limited

Figure 10-2: Frequent Bus Stop Waiting Area - Wide Pedestrian Zone



or no sides to the shelter, though these designs must be coordinated with the transit operator.

The length of the passenger waiting area should be equal to the distance from the front of the bus to the end of the rear door of the bus. For a standard 40 ft. bus, this distance is typically around 30 ft. For a 60 ft. articulated bus, the length of the passenger waiting area should typically be around 50 ft. In all cases, these distances should be coordinated with the transit operator(s) to understand their vehicle fleet. Figure 10-2 shows an example of a Frequent Bus Stop waiting area with a wide pedestrian zone.

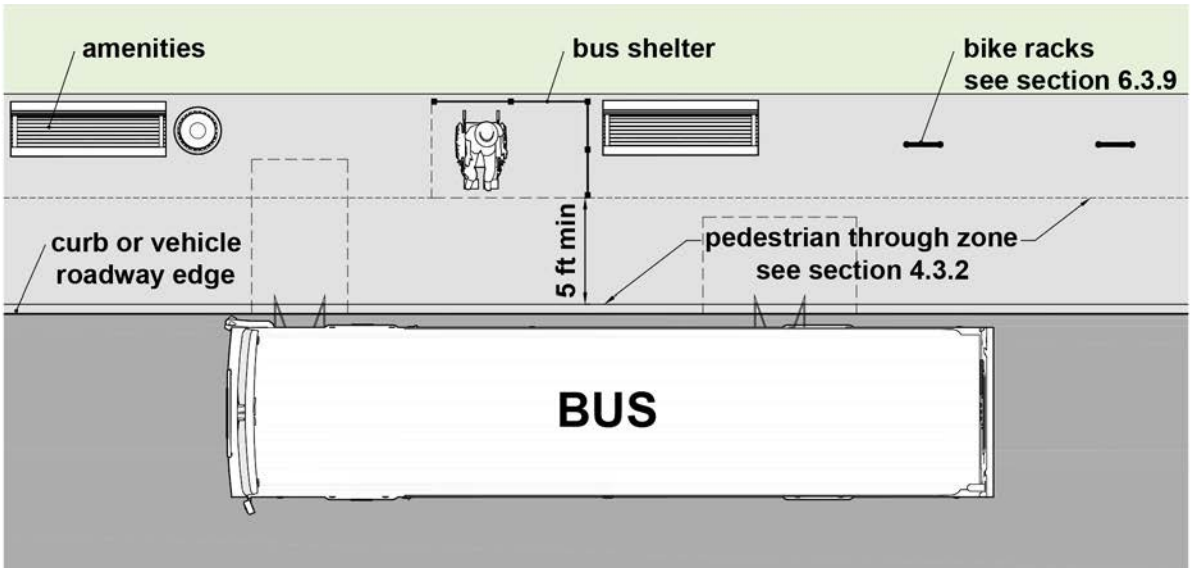
Constrained Pedestrian Zone

In contexts with high usage stops located where the width of the pedestrian zone is constrained, typically narrower than 12 ft., elements of the passenger waiting area can overlap with the Pedestrian Through Zone as long as accessible widths are maintained.

The Pedestrian Through Zone can be situated adjacent to the curb and should be a minimum of 5 ft. in width (4 ft., if appropriate passing areas and accessible turning areas are provided), although in areas with high volumes of pedestrian activity these minimum widths are likely to be inadequate (see Section 4.3.2). The 8 ft. by 5 ft. boarding and alighting area is likely to overlap with the Pedestrian Through Zone in this scenario. Passenger amenities can be situated between the Pedestrian Through Zone and the right-of-way line. This arrangement will lead to increased interactions between bus passengers and pedestrians within the Pedestrian Through Zone and should only be used within constrained areas and retrofit situations.

The length of the passenger waiting area should be equal to the distance from the front of the bus to the end of the rear door of the bus. For a standard 40 ft. bus, this distance is equal to 30 ft. For a 60 ft. articulated bus, the length of the passenger waiting area should be 50 ft. Figure 10-3 shows an example of a bus stop waiting area in a constrained environment.

Figure 10-3: Frequent Bus Stop Waiting Area - Constrained Pedestrian Zone



Basic Bus Stop with Amenities

Where bus stop usage is low or moderate, the stop infrastructure footprint may be smaller, but it can still be desirable to provide amenities to improve the comfort of transit riders. In situations where amenities such as shelters or benches are appropriate, they can be placed either within the buffer space (as shown in Figure 10-4) or behind the sidewalk (as shown in Figure 10-5). Coordinate the design and placement of amenities with the need to provide intersection and driveway sight distances. This assessment may require shelters to be constructed without side, or with transparent sides, to maintain sight distances.

Figure 10-4: Basic Bus Stop Waiting Area with Amenities – Separated Sidewalk

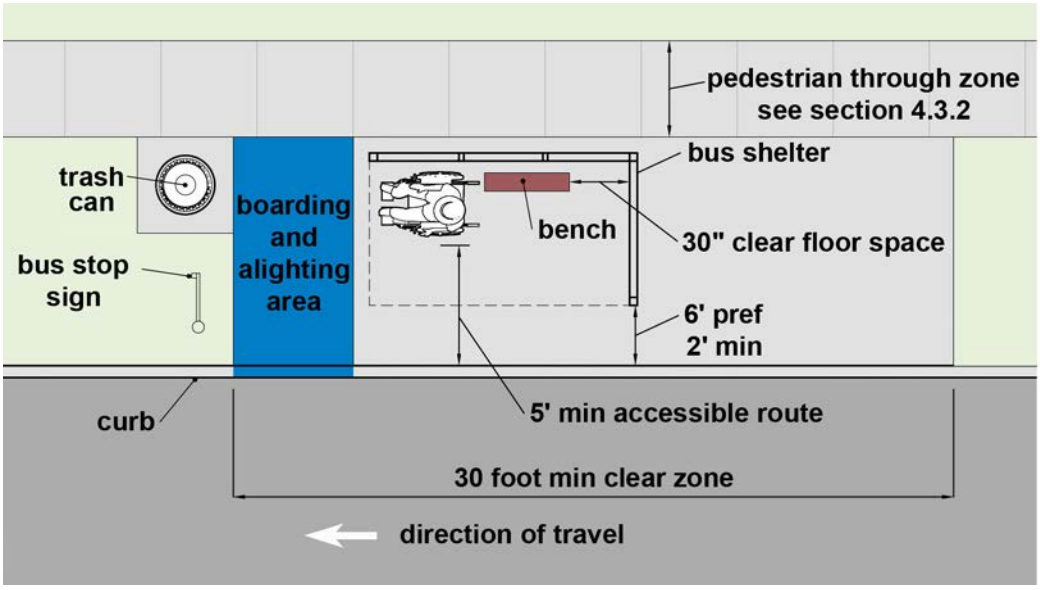
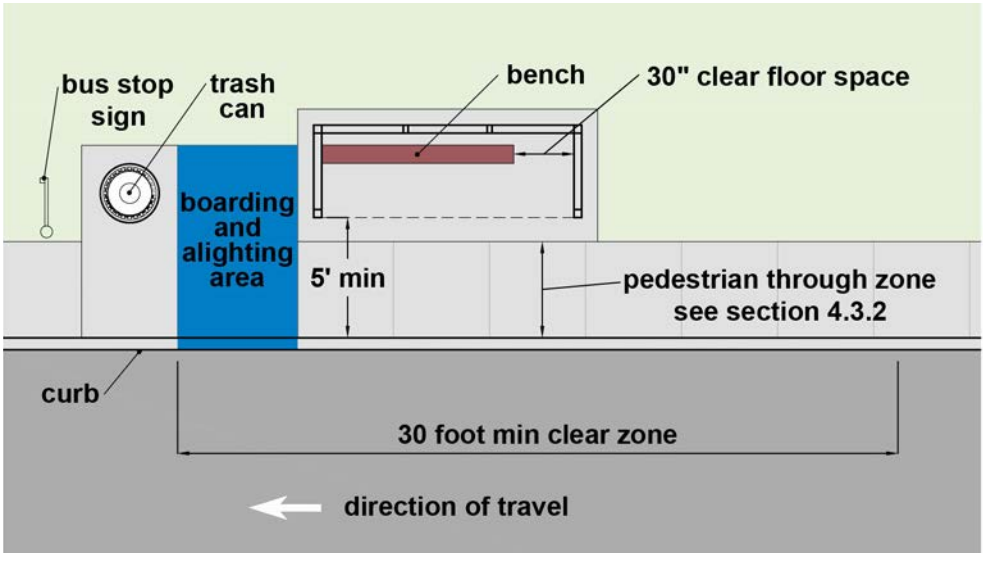


Figure 10-5: Basic Bus Stop Waiting Area with Amenities – Sidewalk Adjacent to Curb



Basic Bus Stop

Where bus stop usage is low or moderate and shelter amenities are not desired, or where the footprint of the project area cannot accommodate a shelter, the stop design still needs an accessible boarding and alighting area and a bus stop sign. Figure 10-6 illustrates the scenario where the sidewalk is separated from the curb by a buffer space and the boarding and alighting area overlaps with the sidewalk. Designers should note the need for a second concrete pad at the rear door so that passengers alighting can step onto a firm and stable surface.

Figure 10-7 illustrates the scenario where the Pedestrian Through Zone is located adjacent to the curb and an extended boarding and alighting area is provided behind the sidewalk.

Figure 10-6: Basic Bus Stop Waiting Area - Separated Sidewalk

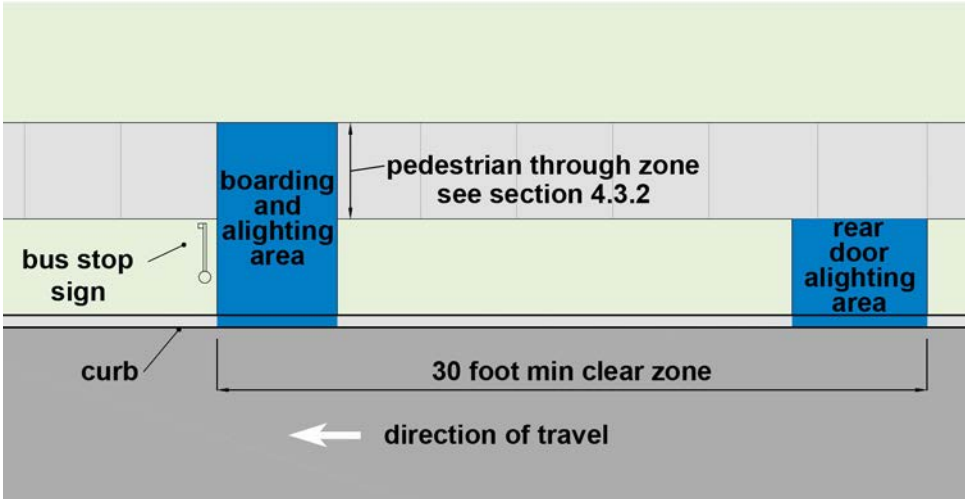
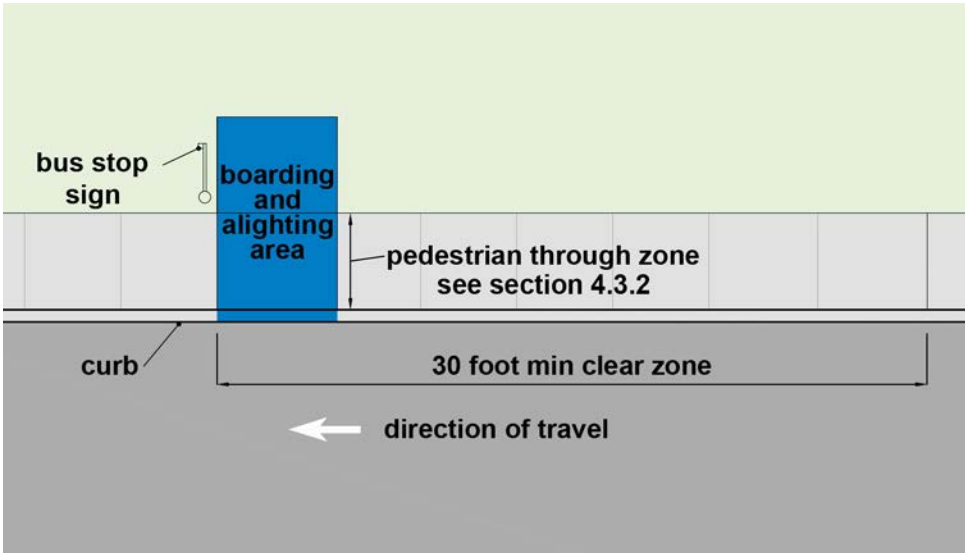


Figure 10-7: Basic Bus Stop Waiting Area – Sidewalk Adjacent to



Uncurbed Roadway

Bus stops on uncurbed roadways can be located within the roadside with flat obstruction-free connections for pedestrians. An 8 ft. by 5 ft. boarding and alighting area is still needed to facilitate accessible access and additional space can be desirable to serve as the waiting area, particularly along higher speed roads.

In some cases it may be desirable to provide a 6 inch high concrete pad in the shoulder as a raised transit stop to better accommodate boarding and alighting, to improve the comfort of waiting transit riders, and to avoid having pedestrians standing in an area of shoulder used for drainage conveyance. The preferred dimensions of a raised transit stop should be at least 8 ft. by 30 ft. exclusive of pedestrian ramps for changing elevations. A pedestrian ramp is needed on both sides of the raised transit stop to connect the platform to the shoulder elevation. These pedestrian ramps should not include detectable warning surfaces because the bottom of ramp facilitate a vertical transition in the Pedestrian Through Zone and not a roadway crossing. Designers should consider the speed of the road, the offset between the edge of travel lane and the raised transit platform, and the design of the approach ends of the platform to avoid introducing an unexpected vertical obstruction close to the travel lane. Ensure that curbs are appropriately tapered to avoid blunt edges and provide right clearance markers, if appropriate, to guide motorists away from the raised transit platform.

10.3.5. Bus Stop Amenities

The passenger waiting experience is impacted by which amenities are provided at a bus stop. The following table provides a list of common amenities and design considerations for each. The selection of each amenity depends on the context of the stop and usage. Some guidance on the selection process is provided within the Waiting Requirements section.

Table 10-4: List of Bus Stop Amenities

Amenity	Design Considerations
Bus Stop Sign	• All bus stops should include a bus stop sign indicating at least the route number(s) served by the stop. • Bus stop signs should be posted at a location that can easily be accessed by and visible to a person standing at the boarding and alighting area. • Bus stop signs may include additional plaques providing route frequency information or tactile information for people with vision disabilities. Additional real-time information screens may also be provided.
Shelter	• Transit shelters design will vary depending on the transit agency, but typically are at least 4 ft. deep. • When the shelter entrance faces the roadway, a 6 ft. buffer is preferred between the shelter and the curb, but at least a 5 ft. clear space width is needed to access the boarding and alighting area from the shelter. • When the shelter entrance faces away from the roadway, a 2 ft. buffer is acceptable between the edge of shelter and face of curb. This design may be appropriate to reduce the spray from vehicles in wet weather conditions. • A 2 ft. buffer should be maintained between the curb and the overhang of any transit shelter roof. • See PROWAG R308.2 for accessibility guidance specific to transit shelters.

Amenity	Design Considerations
Bench	• Benches should be placed a minimum of 5 ft. away from the curb face. • Ensure that 4 ft. of space is provided around benches to accommodate access.
Lighting	• The design of bus stops should typically include pedestrian-scale lighting to illuminate the shelter and bus stop sign. Lamps that are less than 25 ft. high are suitable for the scale of bus stops. • Bus stop lighting creates a better sense of security for passengers and allows operators to see passengers waiting at the bus stop. • Auxiliary lighting may be provided with the shelter itself.
Waste Receptable	• Waste Receptacles should be placed at least 4 ft. from the back of curb and 3 ft. from benches or shelters. • A minimum of 4 ft. should be provided for pedestrian passage adjacent to a waste receptable.
Bicycle Rack	• Bicycle racks should not obstruct access to shelters, benches, or any transit doors, and should be conveniently located near transit stops.

10.4 Locating Bus Stops

This section provides guidance for locating the bus stop zone. The bus stop zone is the paved area where a bus stops and the space that may be required for deceleration, acceleration, and merging into and out of the paved area. The placement and design of the bus stop zone within a street cross-section is dependent on many factors and can be designed to meet several objectives. There are two major aspects of bus stop design: stop placement and stop configuration. The design considerations and design requirements are discussed in Section 10.4.1 and 10.4.2.

10.4.1. Stop Placement

The location of bus stops along a street is referred to as stop placement. Stops can be placed in the following locations:

- Far-side: The bus stop zone is placed for buses to travel through the intersection and stop on the far side of the intersection.
- Near-side: The bus stop zone is placed for buses to stop on the near side of the intersection prior to traveling through it.
- Mid-block: The bus stop zone is placed in between intersections.

Table 10-5 summarizes the advantages, disadvantages, and preferred use of each type of stop placement.

Table 10-5: Advantages and Disadvantages of Types of Stop Placement

Stop Placement	Advantages	Disadvantages	Preferred Use
Far-side	• Far-side stops provide better sightlines for pedestrians at a crosswalk. Pedestrians cross behind the bus and sightlines are not blocked by stopped buses. • The risk of a pedestrian crossing in front of a bus merging back into traffic is reduced. • Far-side stops provide better opportunities for buses to merge back into the travel lane, especially at signalized intersections. • Far-side stops result in reduced queueing behind buses than with near-side operation. • Boarding and alighting activity occurs farther away from the intersection which leads to reduced pedestrian crowding at intersection. • On streets with on-street parking, fewer parking spaces are impacted because of far-side stops.	• Passengers approaching the bus stop from the intersection may not be visible to bus operators. • Bus passengers may have to walk longer to access the crosswalk at an intersection.	• Where high volumes of right-turn vehicle movements occur in the curb lane at the near-side of the intersection. • At locations where a bus left turn is required, a far-side stop placed after the left turn provides better operation. • Locations where transit signal priority is implemented. • Where the far-side traffic volume is lower than the near-side traffic volume.
Near-side	• Near-side bus stops offer better connections to bus stops on the intersecting street that are placed far-side. • Bus operators have better sightlines to customers approaching the bus stop. • Where right-turning vehicle volume from the cross street is high, near-side stops can eliminate interactions between right-turning vehicles and stopped buses.	• Stopped buses obscure sightlines to a stopped bus and/or pedestrian crossing the street. • Buses and vehicles making right turns conflict with each other. • The operational efficiency of the intersection may be reduced in some cases. • Without a receiving lane provided on the far-side of the intersection, merging back into traffic can be challenging at near-side stops. • For pull-out bus stops, a larger pull-in taper is required than with far-side placement.	• Where the near-side traffic volume is lower than the far-side traffic volume • Where a high number of passengers transfer to/from a far-side stop on the intersecting street. • Where right-turning vehicles from the cross street would conflict with a stopped bus far-side. • Where local and rapid transit service require separate stops, a near-side stop can serve the local bus service.

Stop Placement	Advantages	Disadvantages	Preferred Use
Mid-block	• Stop can be located directly in front of a high-demand destination. • Mid-block stops may mean reduced crowding around the bus stop than at intersections. • Can provide suitable bus stop spacing when intersections are not closely spaced.	• There is a risk of unsafe pedestrian crossings at mid-block locations. • Driveways around the bus stop may not have adequate sightlines because of the bus stop. • The distance to connect to bus routes on intersecting streets is increased. • For pull-out bus stops, mid-block stops typically require more space along the curb than far-side or near-side stops.	• Where a significant transit passenger origin or destination is located mid-block. • Where the intersection operations may not be able to accommodate a bus stop. • Where intersections are not closely spaced.

The location of bus stops along a street depends on many factors and requires selection based on a transit agency's design guidance and by the design characteristics of an individual location. For each of these placements, a bus stop may be in-lane or pull-out (see Section 10.4.2). Far-side bus stops are generally preferred for pedestrian safety benefits and operational benefits, but near-side and mid-block bus stops can also be suitable in certain conditions. Where mid-block bus stops are provided, appropriate pedestrian crossings should be provided to ensure that pedestrians do not risk making unsafe crossings (see Section 4.4).

10.4.2. Stop Configuration

The type of stop configuration depends on transit operation requirements, the area context, and the frequency of the service provided. For each of the stop configurations, the stop can be placed either far-side, near-side, or mid-block, depending on the specific needs of the location (see Section 10.4.1).

In-lane Bus Stop

In-lane bus stops allow buses to stop within a travel lane rather than being provided with a pull-out area. Vehicles in the same travel lane must wait for a bus to complete boarding and alighting activities. As no pull-in or pull-out maneuver is required, the designated space required for the bus stop zone includes space for the length of a bus and any buffers required from a crosswalk.

There are operational advantages when the bus does not have to wait for gaps in traffic to pull back into the roadway, such as keeping the dwell time low. This can be particularly beneficial in areas of low ridership and higher traffic volumes. See Bus Bulbs section below.

Table 10-6 and Figure 10-8 provide the minimum design dimensions for in-lane bus stops, though transit agencies or specific transit vehicles may require additional lengths for these configurations.

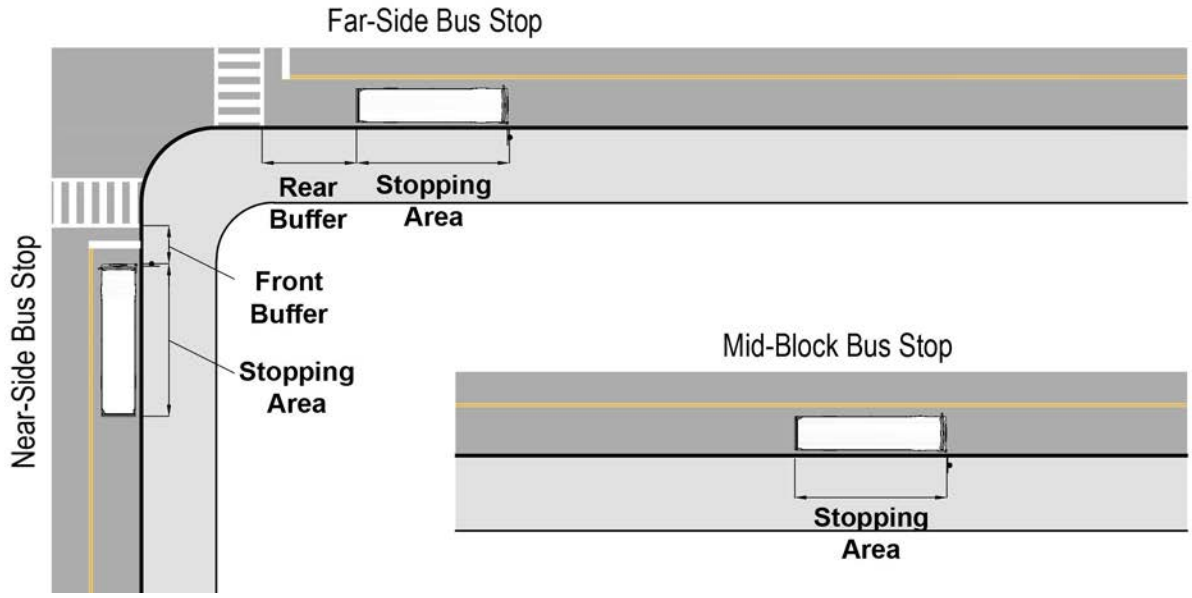
The design of far-side stops after a bus makes a left or right turn should be coordinated with the local transit agency to ensure that the bus fleet in operation can be aligned at the stopping area after the turn movement.

Table 10-6: Dimensions for In-lane Bus Stops

Stop Placement	Rear Buffer 1 (ft)	Stopping Area 4 (ft)	Front Buffer 2 (ft)	Total Length (ft)
Far-side	10 [3]	40	-	50
Far-side after Bus Left Turn	25 [5]	40	-	65
Far-side after Bus Right Turn	55 [5]	40	-	95
Near-side	-	40	10 [2]	50
Mid-block	- [6]	40	-	40

Notes:
For far-side stops, the rear buffer should be measured from the nearest edge of crosswalk to the rear of the bus when it is stopped in the stopping area.
For near-side stops, the front buffer should be measured from the nearest edge of crosswalk to the front of the bus when it is stopped in the stopping area.
Where a single travel lane is available in the direction of travel, additional space should be maintained for a vehicle to queue behind a bus.
A stopping area of at least 60 ft. should be used for 60 ft. articulated buses.
Dimensions assume at least two travel lanes are available in the direction of travel. For single travel lanes and vehicle turning template must be reviewed.
If crosswalks are provided adjacent to mid-block stops, the crosswalk should generally be location behind the bus stop and should be located based on the traffic control type and available sightlines, but should be no less than 10 ft from the rear of the bus when it is stopped in the stopping area.

Figure 10-8: In-lane Bus Stop Zone Dimensions



Bus Bulbs

A bus bulb is a variant of the in-lane bus stop as it is an extension of the curb into the parking lane (i.e., curb extension – See Section 4.5.4), allowing buses to stop within a travel lane for boarding and alighting activities against a curb. Bus bulbs can help reduce transit travel times by reducing the delay associated with re-entering travel lanes. Bus bulbs are typically used on lower speed roadways, with posted speed limits below 35 mph, but can be considered on any roadway with on-street parking.

The width of a bus bulb depends on the width of the adjacent parking lane. Where a parking lane width of 8 ft. is available, the 8 ft. by 5 ft. boarding and alighting area can fit entirely within the bus bulb. A portion of the passenger landing pad may overlap with the Pedestrian Through Zone in constrained locations.

Table 10-7 and Figure 10-9 provide the minimum design dimensions for bus bulbs.

The design of bus bulbs at far-side locations after a bus makes a right turn should be coordinated with the local transit agency to ensure that the bus fleet in operation can be aligned at the stopping area after the turn movement.

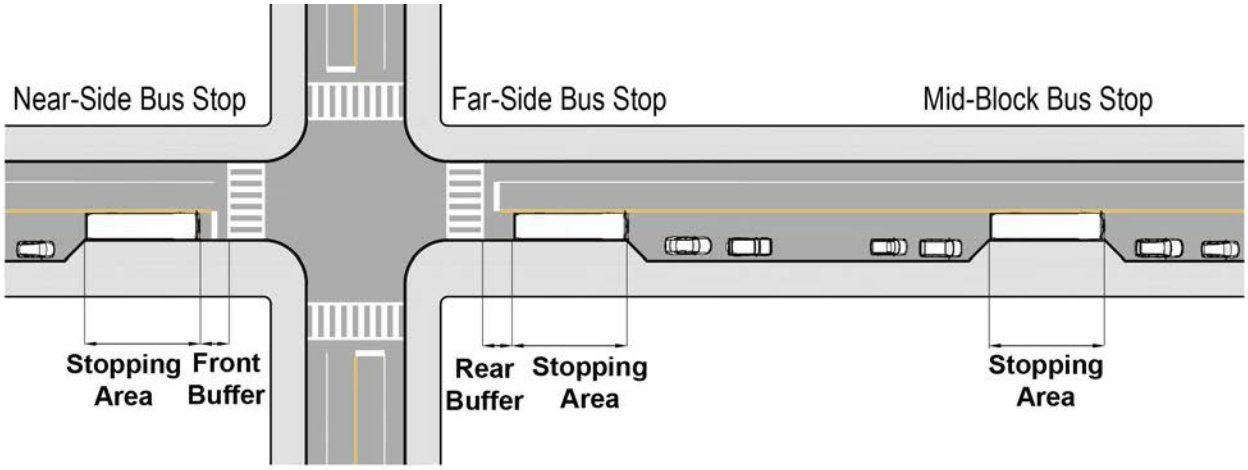
Where a mid-block bus bulb is provided, a safe pedestrian crossing should be provided at the location. To reduce the pedestrian crossing distance at the crosswalk, the curb may be extended at the crossing location. The distance required for the width of the crosswalk and the crosswalk buffer space should be added to the length of the bus bulb provided in Table 10-7.

Table 10-7: Dimensions for Bus Bulb Stops

Stop Placement	Rear Buffer (ft)	Stopping Area [3] (ft)	Front Buffer (ft)	Total Length (ft)
Far-side	10 [1,4]	40	-	50
Far-side after Bus Left Turn	25 [1,4]	40	-	65
Near-side	-	40	10 [2]	50
Mid-block	- [5]	40	-	40

Notes:
For far-side stops, the pull-in taper should be measured from the crosswalk to the rear of the bus when it is stopped in the stopping area, but in constrained areas the pull-in taper can be measured through the intersection.
For near-side stops, the pull-out taper should be measured from the crosswalk to the front of the bus when it is stopped in the stopping area, but in constrained areas the pull-out taper can be measured through the intersection.
A stopping area of 60 ft. should be used for 60 ft. articulated buses.
On single lane-lane roads, additional space should be maintained for vehicles to queue behind a bus.
If crosswalks are provided adjacent to mid-block stops, the crosswalk should generally be location behind the bus stop and should be located based on the traffic control type and available sightlines, but should be no less than 10 ft. from the rear of the bus when it is stopped in the stopping area.

Figure 10-9: Bus Bulb Stop Zone Dimensions for Near-Side, Far-Side, and Mid-block Stop Placement



Pull-out Bus Stop

In this configuration, a bus pulls out of the travel lane and into a designated bus stop location within an adjacent parking lane or into the roadside. After serving the stop, buses pull-out of the stop location and back into the travel lane. Pull-out bus stops can be placed within a parking lane or within the roadside as a bus bay. Pull-out bus stops may be appropriate where stopping in the travel lane is not desirable, such as in the following circumstances:

- Where the pull-out bus stop is used as a queue jump to bypass other vehicles.
- Where a designated timing point requires that a bus does not leave the stop until a scheduled departure time.
- Where the volume of boarding and alighting is significantly high and the dwell time will significantly impact other vehicles in the travel lane.
- Where the posted speed limit on the roadway is higher than 35 mph.

Pull-out stops must be designed to allow buses to turn into the pull-out space and be able to turn back out of the stop zone and merge into the travel lane. The space required for a bus to turn from the travel lane into the stop is called the pull-in taper and the space required to merge back into the travel lane is called the pull-out taper. In cases where the posted speed limit is 35 mph or higher, additional space for buses to decelerate after merging into the bus stop zone and accelerating before merging back into traffic may be appropriate. The pull-out stop lane width should be 11-12 ft. wide, but may be 10 ft. wide where posted speeds are less than 30 mph.

Pull-out bus stops can be found in two different contexts:

- Pull-out bus stop in bus bay – where the curbline or edge of pavement widens to accommodate a dedicated bus stop zone between the typical travel lanes and the sidewalk.
- Pull-out bus stop in parking lane – where a dedicated bus stop zone is provided within the area of an existing parking lane.

Bus Bay

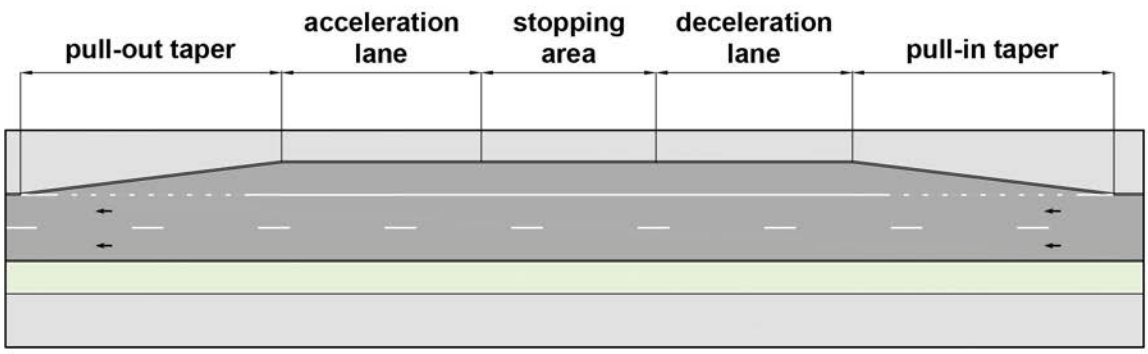
Table 10-8 and Figure 10-10 provide the minimum design dimensions for a pull-out bus stop in a bus bay. Transit agencies may require changes to these dimensions.

Table 10-8: Bus Bay Design Dimensions

Thru Speed	Enter Speed	Length					
		Pull-in Taper	Decel. Lane	Stopping Area	Accel. Lane	Pull-out Taper	Total
mph	mph	ft	ft	ft	ft	ft	ft
<30	<20	5:1 min	None	50	None	3:1 max	130 min
35	25	170	175	50	250	170	825
40	30	190	265	50	400	190	1,095
45	35	210	360	50	700	210	1,530
50	40	230	470	50	975	230	1,955
55	45	250	595	50	1,400	250	2,545
60	50	270	735	50	1,900	270	3,225

Notes:
Entering speed assumed to be 10 mph of through-speed at end of taper.
Taper lengths based on 12 ft. bus bay width. 10 ft. minimum is acceptable for speeds under 30 mph.
Add 20 ft. to length of stopping area if used by 60 ft. long articulated buses.
Deceleration rate of 2.5 mph/sec is assumed.

Figure 10-10: Bus Bay Design Dimensions



Bus Stop Zone in Parking Lane

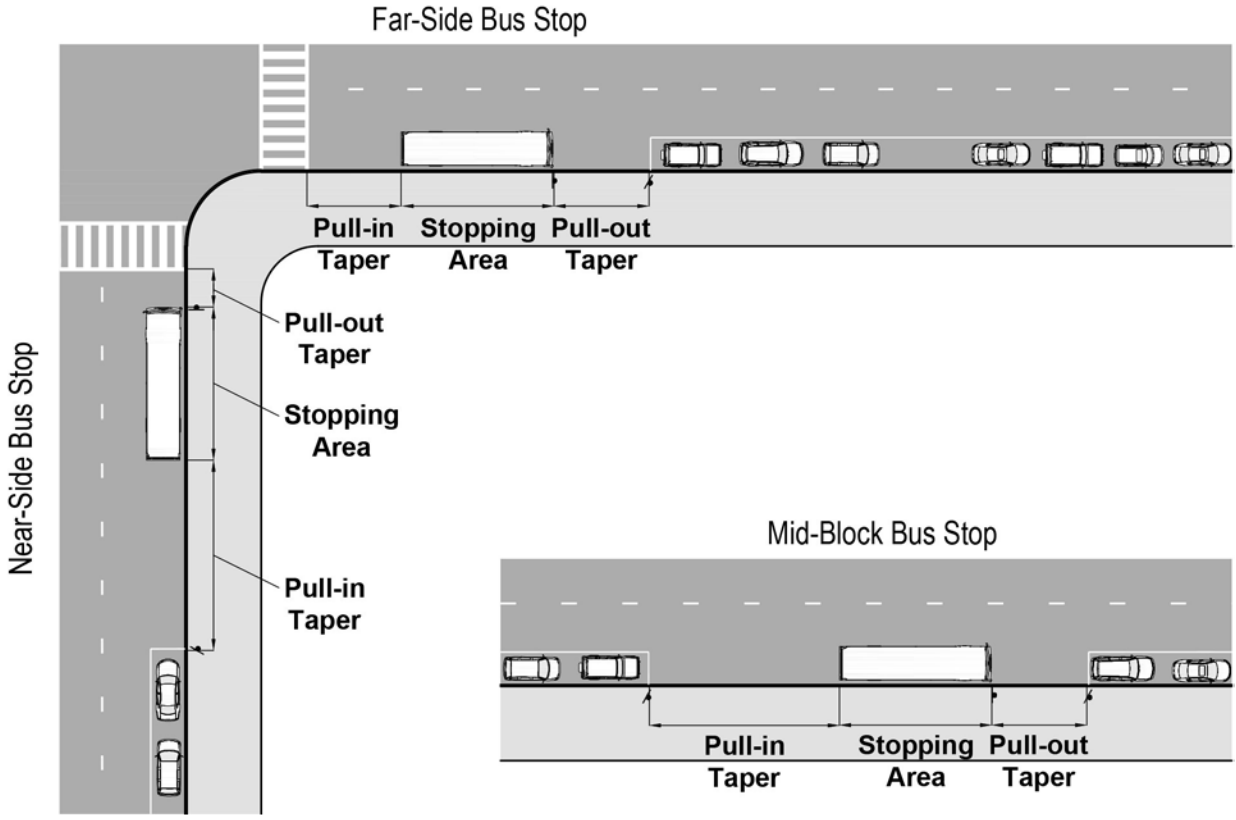
In areas with roadway speeds of 35 mph or less and parking lanes, pull-out bus stops can be designed into the parking lane. In this scenario the bus stop zone includes a pull-in taper, a pull-out taper, and the stopping area for the bus. Table 10-9 and Figure 10-11 provide the minimum dimensions for bus stop zones in parking lanes for far-side, near-side, and mid-block placements.

Table 10-9: Dimensions for Bus Stop Zone in Parking Lane

Stop Placement	Pull-in Taper (ft)	Stopping Area 3 (ft)	Pull-out taper (ft)	Total Bus Stop Zone (ft)
Far-side	10 [1]	40	25	75
Far-side after Bus Left Turn	25 [1]	40	25	90
Far-side after Bus Right Turn	55 [1]	40	25	120
Near-side	50	40	10 [2]	100
Mid-block	50	40	25	115

Notes:
For far-side stops, the pull-in taper should be measured from the crosswalk to the rear of the bus when it is stopped in the stopping area, but in constrained areas the pull-in taper can be measured through the intersection.
For near-side stops, the pull-out taper should be measured from the crosswalk to the front of the bus when it is stopped in the stopping area, but in constrained areas the pull-out taper can be measured through the intersection.
A stopping area of at least 60 ft. should be used for 60 ft. articulated buses.

Figure 10-11: Pull-out Bus Stop Zone Dimensions



10.5 Integrating Bicycle Facilities with Transit

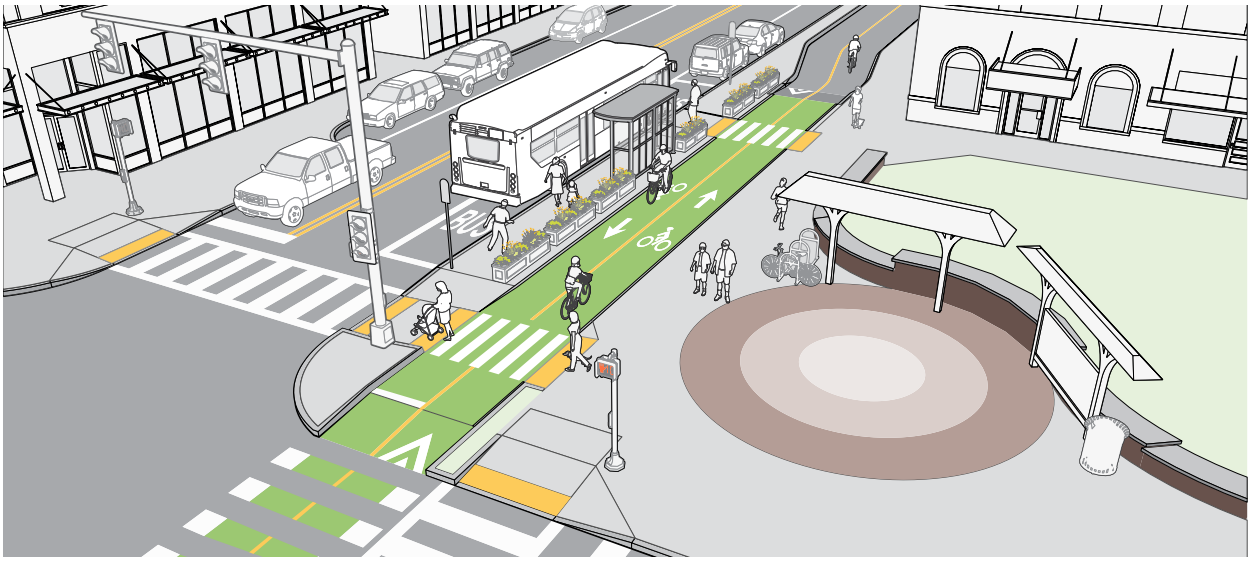
In locations with on-street bicycling facilities, bus stops should be designed to address interactions between bicyclists, transit riders, and transit vehicles. Three configurations can be used to manage bicycle and bus stop conflicts:

- Floating Bus Stop – the bike lane is located behind the bus boarding and alighting area requiring pedestrians to cross the bike lane between the sidewalk and the transit platform area.
- Constrained Floating Bus Stop – the bike lane ramps up to the curb height for the length of the transit stop and serves as a shared space for transit riders and bicyclists.
- Bicycle Facility Between Travel Lane and Bus Stop – the bus pulls into or through the bike lane space to access the bus stop.

10.5.1. Floating Bus Stop

In this scenario a transit platform is provided between the general purpose lane and the bike lane. It is referred to as a floating bus stop because the boarding and alighting area is separated from the rest of the sidewalk area by the bike lane. This scenario is preferred for bicyclists and transit operators because it effectively eliminates the conflicts between bicyclists and transit vehicles that are typical at conventional transit stop designs. This design also helps to maintain the Pedestrian Through Zone by separating the space for passenger boarding and alighting from the sidewalk area. This design is most typically used where separated bike lanes are provided along a street but can also be used with other bike lane configurations to eliminate the bus-bike conflict when the boarding and alighting volumes or volumes of bicyclists are high.

Figure 10-12: Far-side Floating Bus Stop with Intermediate-Level Two-Way Separated Bike Lanes



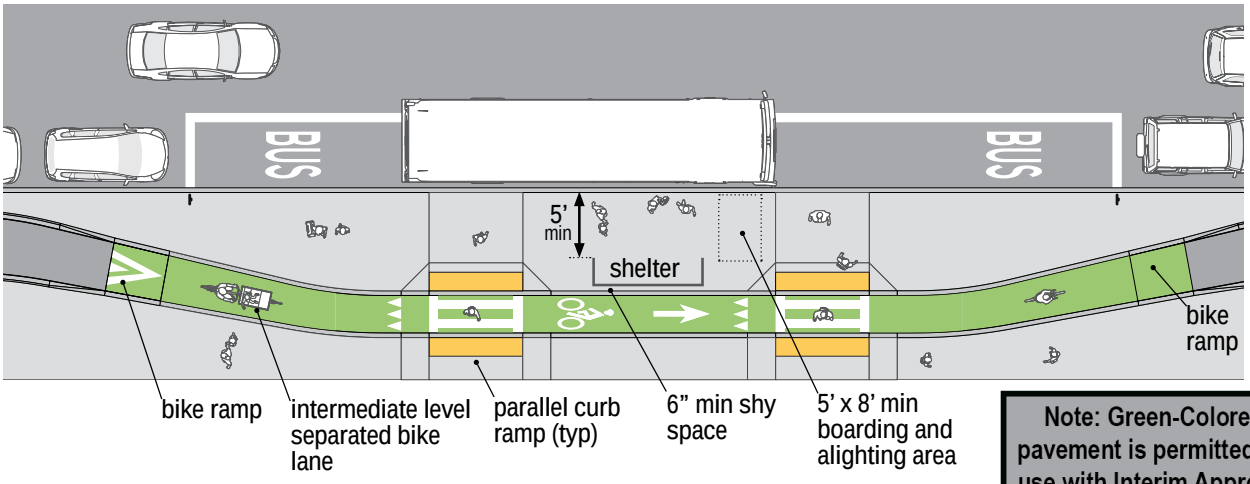
The bike lane behind a floating bus stop is a separated bike lane and should be designed according to the principles of Section 6.3.7. The elevation of the bike lane (at street-level, sidewalk-level, or intermediate level) will affect the design of curb ramps, the sidewalk, and floating bus stop platform to provide pedestrian access and meet accessibility guidelines. To address pedestrian desire lines, a curb ramp should be provided at each end of the floating bus stop, and where possible railings should be provided between the bus stop and bike lane to guide pedestrians to the intended crossing areas (see Shy Distance – Section 3.7.2). For floating bus stops at intersections, one of the pedestrian access points should be integrated into the intersection curb ramp design if practicable; Figure 10-12 shows an example of this configuration.

The floating bus stop area must be wide enough to accommodate the 8 ft. by 5 ft. wide boarding and alighting area, and the designer must carefully consider the placement of curb ramps, railings, and shelters to ensure this space is maintained. The bike lane alignment may shift farther from the roadway (as shown in Figure 10-13) in order to provide the necessary boarding and alighting area width. The bus stop must also be long enough to provide access for the front and rear doors of the bus. See DWG 10-1.1 and DWG 10-1-4 for additional design details.

Where a bus shelter is provided on a floating bus stop, sightlines between pedestrians and bicyclists must be maintained to ensure that bus passengers alighting the bus are visible prior to approaching the crosswalk across the bike lane. This often means providing shelters with transparent sides are recommended to help ensure that sightlines are maintained. Shy distances between the bike lane and shelter must also be considered (see Section 3.6.2).

Optional BIKES YIELD TO PEDESTRIANS sign (R9-6) and yield lines may be installed at the approach to uncontrolled crosswalks across the bike lane to reinforce that pedestrians have the right-of-way at the crosswalks. Engagement with pedestrians with disabilities is also recommended during the design process to discuss how the floating bus stop is intended to operate and discuss other design elements that can make the transit stop easier to locate and access.

Figure 10-13: Mid-block Floating Bus Stop with Intermediate-Level One-Way Separated Bike Lane



10.5.2. Constrained Floating Bus Stop

Where space is constrained and a full floating bus stop cannot be accommodated, and where boarding and alighting volumes are low, a portion of the boarding and alighting area may be shared with the bike lane. In this configuration, the bike lane ramps up to the height of the sidewalk and is maintained at this elevation for the length of the bus stopping area. In some cases, it will be desirable to end the bike lane and provide a bike ramp to transition to a shared use path at the transit stop.

If a constrained floating bus stop is used, it should include at least a 4 ft wide step-out area so that alighting passengers are not stepping directly into the bike lane. The bike lane width may be narrowed through the bus stop area to a minimum of 3 ft, but bike ramp widths must be at least 4 ft. wide at their narrowest point. See DWG 10-1.3 for additional design details.

The bus stop and bike lane space must be obstruction free. A BIKES YIELD TO PEDESTRIANS sign (R9-6) and yield lines should be provided prior to the bus stop zone. Where a transit shelter is provided within 3 ft of the bike lane, it should typically face away from the bicycle lane so that the accessible turning space does not overlap with the bike lane, to discourage pedestrians from immediately crossing the bike lane from the shelter, and to channelize pedestrians toward the boarding and alighting area.

If a bike lane is maintained through the bus stop area, provide detectable warning surfaces between the bike lane and sidewalk for the length of the bus stop and across the tops of the bike ramps at each end of the bus stop. A directional indicator may be considered in the sidewalk area, located adjacent to the detectable warning surface, to orient pedestrians with vision disabilities to the location of the boarding and alighting area (see Section 4.3.3 and DWG 10-1.4).

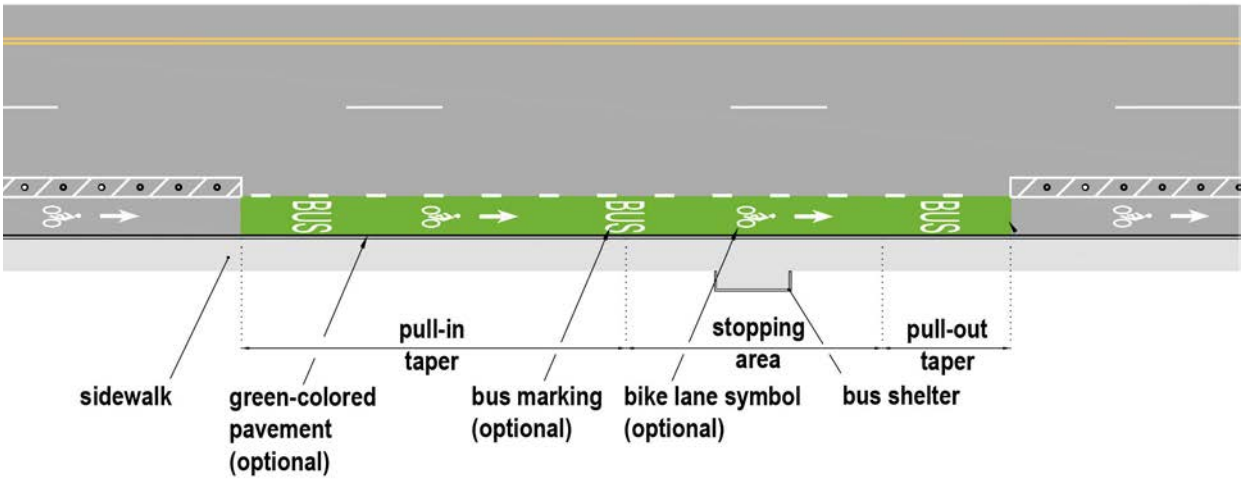
Engagement with pedestrians with disabilities is recommended during the design process to discuss how the shared stop is intended to operate and discuss other design elements that can make the transit stop easier to locate and access. Engagement with the general public is also recommend, along with supplemental signs and markings to reinforce that pedestrians should not stand in the bike lane and instead wait in the passenger waiting area until their bus arrives.

10.5.3. Bicycle Facility Between Travel Lane and Bus Stop

In most conventional bike lane locations, and for some constrained separated bike lane locations, the bus stopping area may need to be shared with the bike lane space. In this scenario buses stop within the bicycle facility. This situation should be discouraged in cases where bus headways are 15 minutes or less. A dotted white lane line should be provided along the length of the pull-in taper, stop area, and pull-out taper. BUS and bike lane or shared lane pavement markings may be considered for use within this shared space to communicate to transit drivers and to bicyclists that this is a shared space. At locations with high volumes of bicyclists, green-colored pavement may be considered. See Figure 10-14.

In a Pull-Out Bus Stop configuration, the bus may pull through the bike lane to access the bus stop area. In these situations, the bike lane lines should be dashed for the total length of the stop area and the pull-in and pull-out tapers (see Section 10.4.2); however, if boarding and alighting volumes are very low, the bike lane lines may remain solid through the bus stop.

Figure 10-14: Bicycle Facility Between Travel Lane and Bus Stop



10.6 Bus-Only Lanes

Bus-only lanes designate the use of a travel lane for exclusive bus use. Bus lanes can improve transit speeds significantly by separating buses from general purpose traffic. Travel lanes reserved exclusively for buses should be 11-12 ft. wide.

Bus-only lanes should be accompanied with a BUS LANE sign (R3-5gP). The sign may be side-mounted or overhead-mounted where possible.

A Bus Only pavement marking shall be positioned laterally in the center of the bus lane (OMUTCD Section 3D.01). The markings may be spaced as close as 80 ft. apart on city streets or as far apart as 1,000 ft. on freeways.

The lane marking requirements for bus-only lanes are described in the OMUTCD in Section 3D.02. Table 10-10 provides a summary for bus-only lanes on the right or left side of the roadway or general purpose lanes.

In some instances, the bus lane may allow for right-turns (or left-turns if bus lane is on left side of a one-way street) to be made from the bus lane. When this occurs, non-bus vehicles are typically restricted to only turning movements and cannot travel for an extended length in the bus lane. Signage and pavement markings should be used to communicate this operation to vehicles and the bus lane paint may be dashed rather than solid in areas where other vehicles are permitted.

If a bus-only lane is provided on a street that does not include other bicycle facilities, it will likely be used by bicyclists because there are typically fewer motor vehicles using this lane. Because the bus-only lane is for the exclusive use of transit vehicles, if the bus-bike operation is expected and desired, designers should instead consider a bus-bike lane (see Bus-Bike Lane section below).

Table 10-10: Standard Edge Line and Lane Line Markings for Preferential Lanes

Type of Preferential Lane	Left Edge Line	Right Edge Line
Contiguous, Left Side	A normal solid yellow line	• A wide solid double white line where crossing is prohibited (Drawing A Figure 3D-3 OMUTCD). • A wide solid single white line where crossing is discouraged (Drawing B Figure 3D-3 OMUTCD). • A wide broken single white line where crossing is permitted (Drawing C Figure 3D-3 OMUTCD).
Contiguous, Right Side	• A wide solid double white line where crossing is prohibited (Figure 3D-3 OMUTCD). • A wide solid single white line where crossing is discouraged. • A wide broken single white line where crossing is permitted (Figure 3D-3 OMUTCD). • A wide dotted single white line where crossing is permitted for any vehicle to perform a right-turn maneuver (Figure 3D-3 OMUTCD). • A normal solid double yellow line on one-way streets with a counterflow bus only lane.	A normal solid single white line (if necessary).

10.7 Bus-Bike Lanes

Bus-bike lanes are a shared lane for the exclusive use of transit and bicyclists. Bus-bike lanes may be considered on streets that do not include other on-road bicycle facilities. Bus-bike lanes have the challenge that they do not alleviate the bike-bike conflicts discussed above, so in congested conditions buses typically cannot pass slower-moving bicyclists and bicyclists typically can only pass buses at bus stops if gaps are available in the general purpose lane.

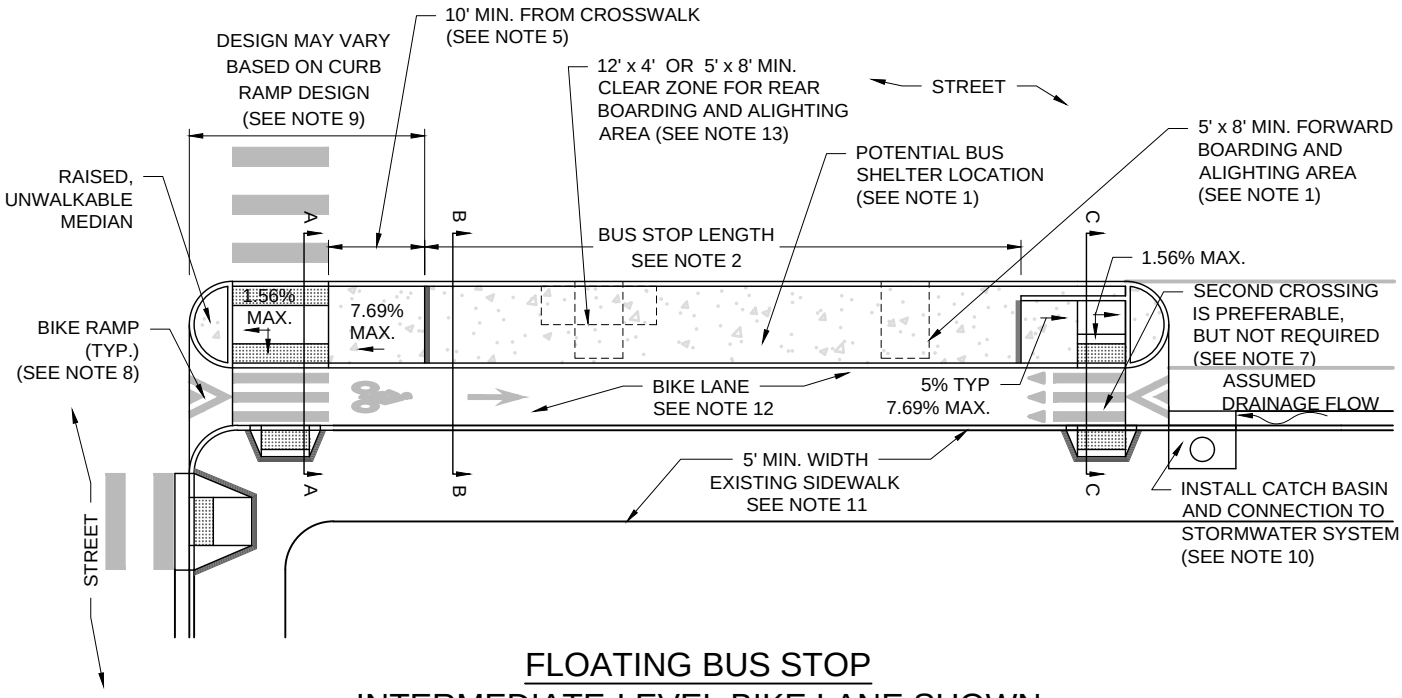
Bus-bike lanes may be appropriate on lower-speed streets where bus schedules would accommodate buses operating at speeds of 20 mph or less, and where transit headways are 4 minutes or more. They may also be useful on one-way streets where a counterflow bus lane is provided.

If a bus-bike lane is provided, it should include pavement markings indicating Bike Bus Only, or Bus Only along with shared lane markings.

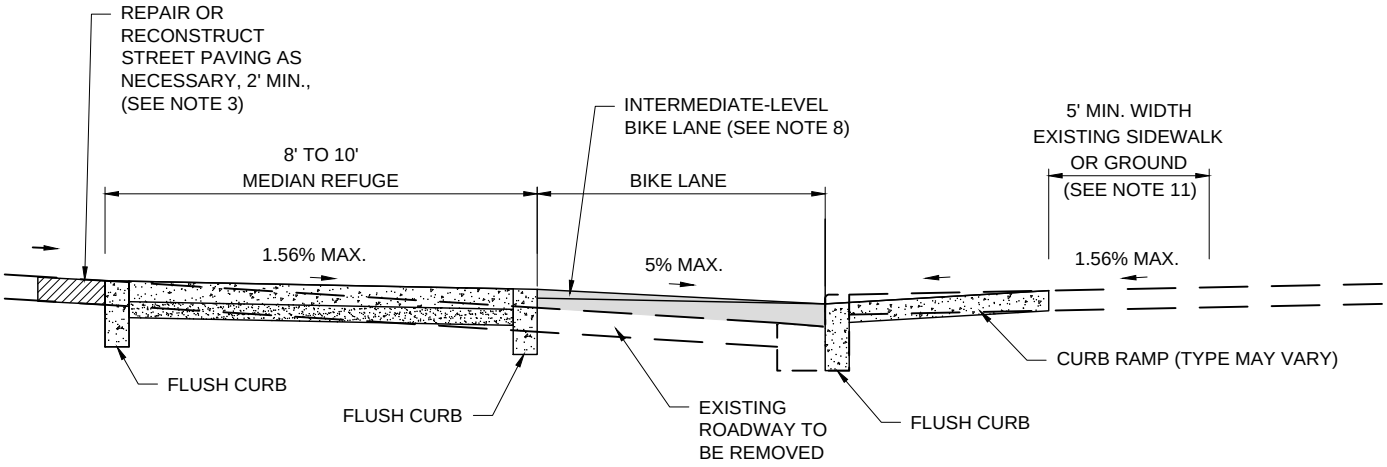
FLOATING BUS STOP DETAILS

DWG 10-1.1

REFERENCE SECTIONS
4.5.3, 6.3.7, 6.3.8,
6.5.2, 7.2, 10.5



FLOATING BUS STOP
INTERMEDIATE-LEVEL BIKE LANE SHOWN

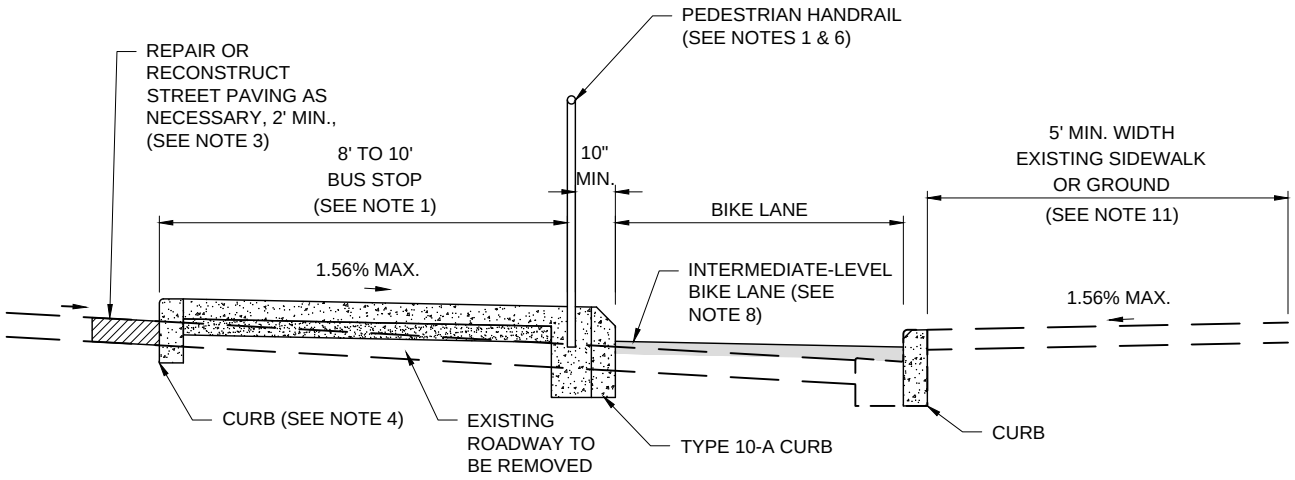


SECTION A-A
FLOATING BUS STOP INTERSECTION CROSSWALK

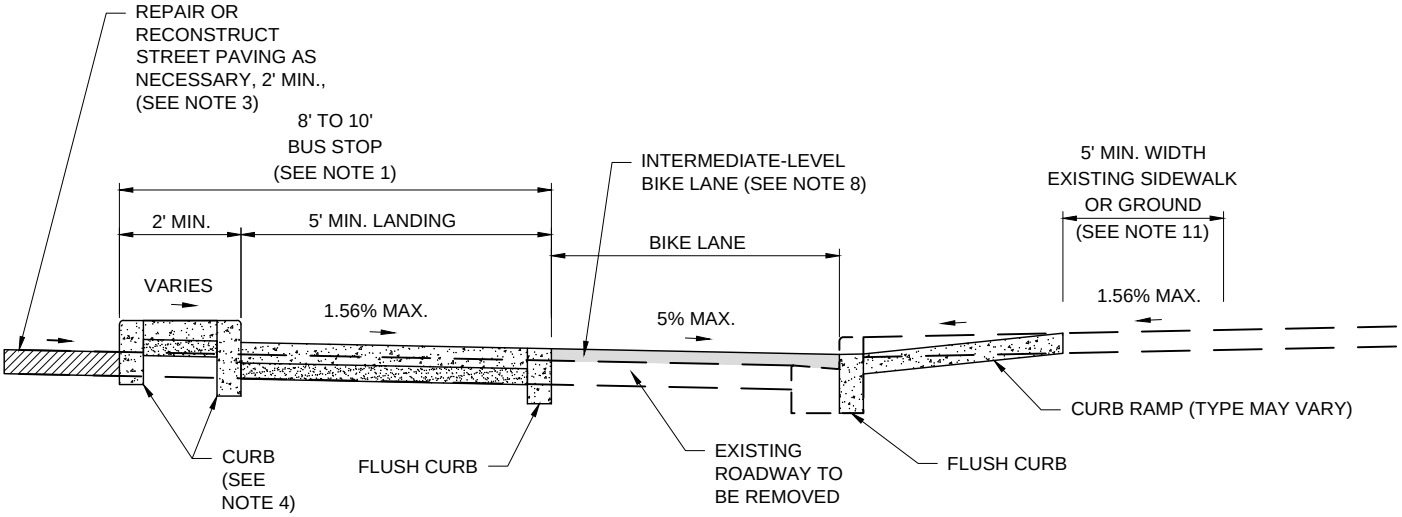
FLOATING BUS STOP DETAILS

DWG 10-1.2

REFERENCE SECTIONS
4.5.3, 6.3.7, 6.3.8,
6.5.2, 7.2, 10.5



SECTION B-B
FLOATING BUS STOP

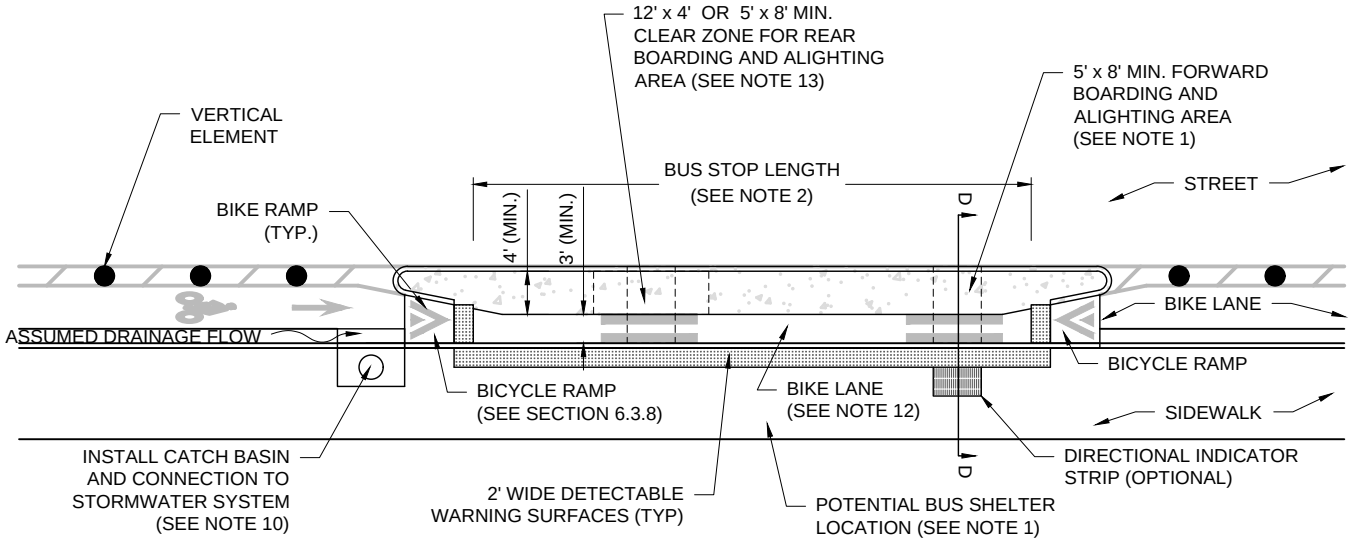


SECTION C-C
FLOATING BUS STOP CROSSWALK

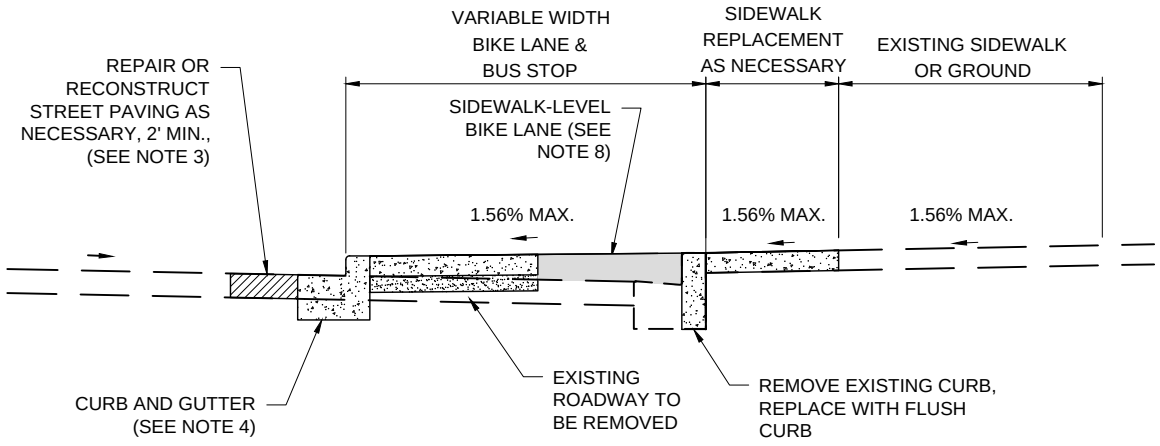
FLOATING BUS STOP DETAILS

DWG 10-1.3

REFERENCE SECTIONS
4.5.3, 6.3.7, 6.3.8,
6.5.2, 7.2, 10.5



FLOATING BUS STOP
CONSTRAINED CONFIGURATION

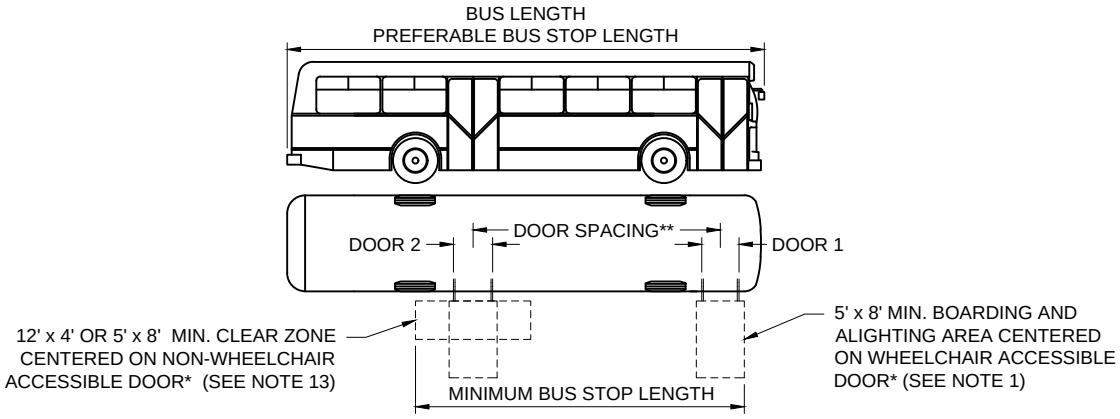


SECTION D-D
CONSTRAINED FLOATING BUS STOP

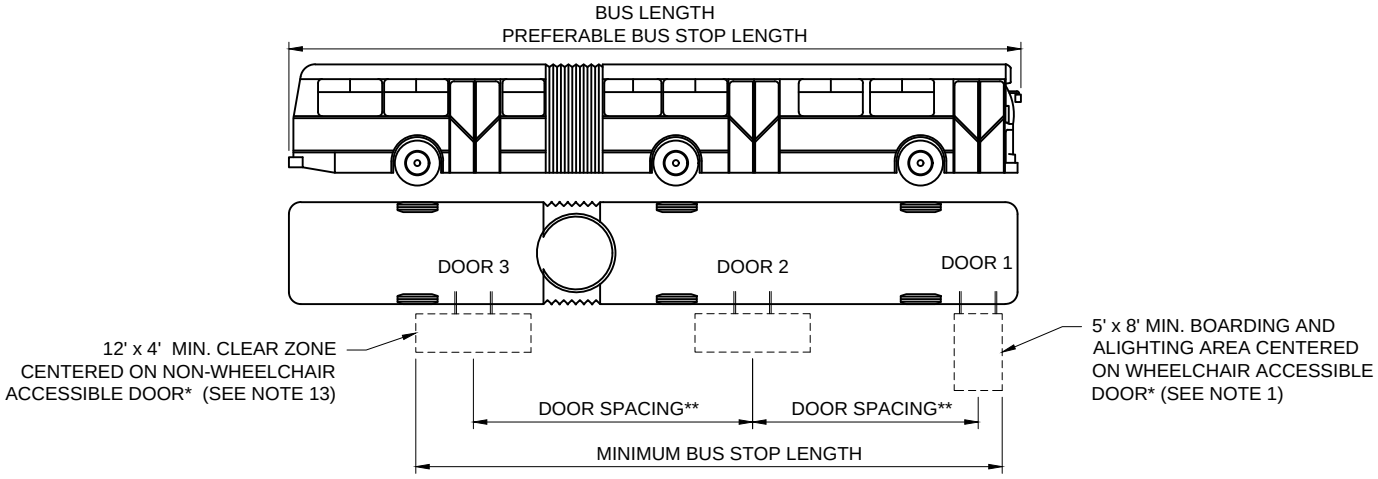
FLOATING BUS STOP DETAILS

DWG 10-1.4

REFERENCE SECTIONS
4.5.3, 6.3.7, 6.3.8,
6.5.2, 7.2, 10.5



BUS STOP LENGTH
STANDARD BUS



BUS STOP LENGTH
ARTICULATED BUS

* WHEELCHAIR ACCESSIBLE DOORS ARE TYPICALLY LOCATED AT THE FRONT OF THE BUS. IF ACCESSIBLE DOOR IS AT REAR OF BUS, 5' x 8' BOARDING AND ALIGHTING AREA MUST BE LOCATED AT REAR DOOR AND 12' x 4' BOARDING ALIGHTING AREA WILL BE LOCATED AT FRONT DOOR. ENSURE THAT ACCESSIBLE AREAS ARE PROVIDED BASED ON ALL BUSES EXPECTED TO USE THE BUS STOP.

** DOOR SPACING MEASURED CENTER TO CENTER ON THE DOORS.

FLOATING BUS STOP DETAILS

DWG 10-1.5

REFERENCE SECTIONS
4.5.3, 6.3.7, 6.3.8, 6.5.2, 7.2, 10.5

NOTES

1. A MINIMUM 5-FOOT WIDE BY 8-FOOT DEEP BOARDING AND ALIGHTING AREA, WITH A MAXIMUM SLOPE OF 1.56% IN ANY DIRECTION, IS REQUIRED AT FORWARD LOADING AREA ADJACENT TO THE BUS DOOR. THE 8-FOOT DEPTH MAY INCLUDE THE ADJACENT CURBLINE, BUT IS EXCLUSIVE OF ANY RAILING OR SLOPING OR MOUNTABLE CURB SPACE; AS SUCH THE PHYSICAL WIDTH OF THE BUS STOP MAY NEED TO EXCEED 8 FEET. A 4 FOOT MINIMUM CLEAR ACCESSIBLE ROUTE MUST BE PROVIDED BETWEEN THE BOARDING AND ALIGHTING AREA AND THE SIDEWALK. AN ACCESSIBLE ROUTE MUST ALSO BE PROVIDED BETWEEN ANY PROVIDED BUS SHELTERS AND THE BOARDING AND ALIGHTING AREA. IF A BUS STOP SERVES MULTIPLE TRANSIT VEHICLE STOPS SIMULTANEOUSLY, BOARDING AND ALIGHTING AREAS MUST BE PROVIDED AT EACH VEHICLE DOOR AND ACCESSIBLE ROUTES PROVIDED ACCORDINGLY.

2. THE MINIMUM BUS STOP LENGTH IS BASED ON ANTICIPATED BUS TYPES AND DESCRIBED ON SHEET 4, BUT THE PREFERABLE LENGTH IS BASED ON THE LENGTH OF THE BUS(ES) EXPECTED TO USE THE BUS STOP. IF MULTIPLE BUSES ARE EXPECTED TO USE THE STOP AT THE SAME TIME, THE LENGTH SHOULD BE BASED ON THE BUS LENGTH(S) WITH 20-FEET OF SEPARATION BETWEEN THE BUSES. THE LENGTH OF A BUS STOP IS EXCLUSIVE OF ALL PEDESTRIAN RAMPS.

3. MODIFICATIONS TO EXISTING STREET PAVING, MILL AND OVERLAY ASPHALT OR COMPLETELY RECONSTRUCT PAVING AS NECESSARY TO RESTORE A SMOOTH TRANSITION AND STREET CROWN. CURB WITH GUTTER MAY BE USED ALONG THE STREET EDGE WHERE NECESSARY TO IMPROVE CONSTRUCTABILITY OR TO MANAGE STORMWATER FLOW.

4. CURB HEIGHT MAY VARY BASED ON EXISTING OR PROPOSED STREET CROSS SLOPES. CURB HEIGHTS LESS THAN 4 INCHES REQUIRE APPROVAL FROM THE OFFICE OF ROADWAY ENGINEERING.

5. BUFFER FROM CROSSWALKS SHOULD BE ADJUSTED BASED ON BUS STOP CONFIGURATION. SEE MDG SECTION 10.4.

6. A HANDRAIL IS REQUIRED IF THE CURB REVEAL (DROP-OFF FROM THE BUS STOP TO THE ADJACENT BIKE LANE) EXCEEDS 8 INCHES. HOWEVER, A HANDRAIL MAY BE CONSIDERED FOR ANY CURB REVEAL OR ADJACENT TO SIDEWALK LEVEL BIKE LANES TO CHANNELIZE PEDESTRIANS TO THE CROSSWALKS.

7. PEDESTRIAN CROSSINGS FROM THE SIDEWALK TO BUS STOP MAY BE PROVIDED AT INTERSECTIONS, AT LOCATIONS SEPARATE FROM THE INTERSECTION, AND/OR AT THE ENDS FARTHEST FROM INTERSECTIONS. TWO PEDESTRIAN CROSSINGS ARE PREFERABLE BASED ON NATURAL PEDESTRIAN DESIRE LINES.

8. PROVIDE BIKE RAMP FROM STREET-LEVEL TO INTERMEDIATE-LEVEL WHERE GRADE CHANGES ARE DESIRABLE. BIKE RAMP WILL BE OMITTED IF BIKE LANE WILL REMAIN AT STREET-LEVEL ALONG THE FLOATING BUS STOP. SIDEWALK-LEVEL BIKE LANES SHOULD BE DISCOURAGED UNLESS BOTH SIDES OF THE BIKE LANE ARE DETECTABLE TO PEDESTRIANS AND CAN GUIDE THEM TO THE CROSSING.

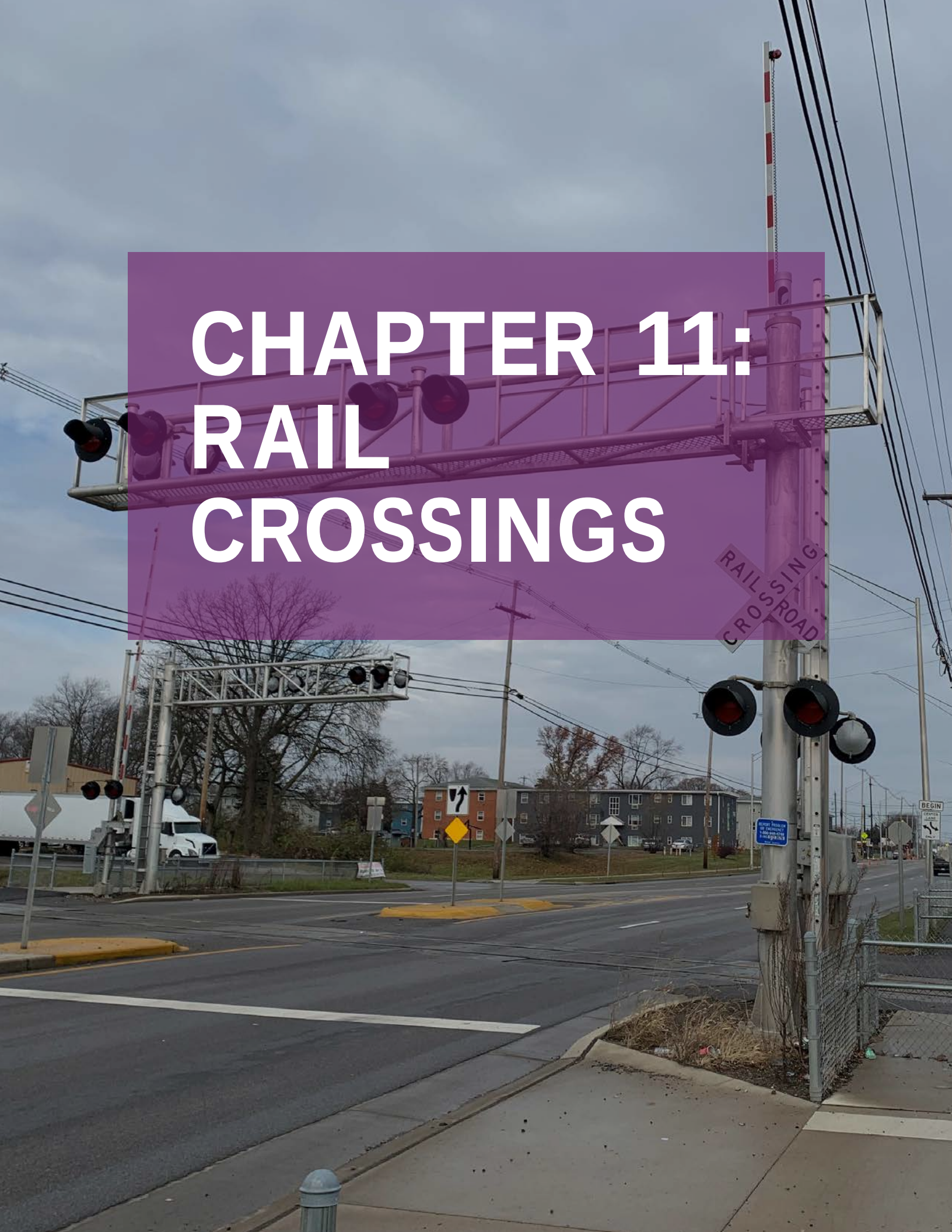
9. THE INTERSECTION CORNER RADIUS SHOULD STRIVE TO PROVIDE THE SMALLEST POSSIBLE CORNER RADIUS BASED ON DESIGN VEHICLES. SEE MDG SECTION 7.2.

10. WHERE POSITIVE DRAINAGE CANNOT BE ACHIEVED ALONG CURBLINES, INSTALL CATCH BASIN AND CONNECT TO EXISTING STORMWATER SYSTEM.

11. AT LOCATIONS WHERE THE SIDEWALK IS LESS THAN 5 FEET IN WIDTH, A CONSTRAINED STOP SHOULD BE CONSIDERED.

12. THE BIKE LANE SURFACE SHOULD CONTRAST WITH THE ADJACENT SIDEWALK AND BUS STOP. GREEN COLORED PAVEMENT MAY BE USED.

13. A MINIMUM 12 FOOT BY 4 FOOT CLEAR SPACE, WITH A MAXIMUM SLOPE OF 1.56% IN ANY DIRECTION IS RECOMMENDED AT ALL REAR BUS DOORS. IF THE REAR DOOR SERVES AS THE WHEELCHAIR ACCESSIBLE LOADING DOOR, A 5 FOOT BY 8 FOOT LOADING AREA IS REQUIRED.



CHAPTER 11: RAIL CROSSINGS

Chapter 11: Rail Crossings

Rail crossings can present unique challenges to non-motorized traffic. Inadequate traffic control devices may lead to confusion about how and when it is safe to cross the tracks. Additionally, crossing tracks for railroads, trolleys, streetcars, etc. can pose a physical challenge as the flangeway gaps may be a tripping hazard for a person walking and may entrap wheelchair casters or a bike wheel. This chapter provides guidance to support decision-making related to the identification of appropriate traffic control devices for walkways and bikeways for at-grade rail crossings where traffic signals are not provided in accordance with Part 8 of the OMUTCD. Designers should refer to Chapter 10 where highway traffic signals are used as a rail crossing's primary control. The geometric design guidance provided in Section 11.1 is independent of traffic control devices and is therefore potentially applicable to all at-grade rail crossings.

Railroad and Highway Right-of-Way

Tracks that are not continuously within the roadway (e.g., not a trolley or streetcar) typically have independent right-of-way that typically supersedes the highway right-of-way at a crossing. In most cases, the owners of the railroad right-of-way are responsible for the maintenance of anything in the right-of-way. This chapter is intended to facilitate discussions with rail owners, but the rail owners ultimately have jurisdiction over any work that occurs within their right-of-way.

Any design that occurs within the railroad right-of-way must be coordinated with the owner of the railroad right-of-way. If ODOT funding is used, the Ohio Rail Development Commission (ORDC) should also be consulted, and the ORDC may provide conceptual or preliminary reviews before submission to the railroad owner. The coordination process can take an extended period of time, so it is recommended that this coordination begin as early as possible so the design team and railroad owner can determine the preferred treatment and ensure it can be accommodated within the anticipated project schedule and contract documents.

Where work extends outside of the railroad right-of-way, designers should assess if the highway right-of-way is sufficient for the preferred treatment. Acquiring additional right-of-way can be costly and may affect the project schedule. Any right-of-way issues should be identified and resolved as early as possible to ensure the recommended treatment(s) can be built as intended.

Design Considerations

Designers should consider the following five topics during the design of at-grade rail crossings to accommodate pedestrians and bicyclists:

1. Provision of Access and Design for Pedestrians and Bicyclists (Section 11.1).
2. Evaluate Available Sight Distance (Section 11.2).
3. Evaluate Primary Control for Pedestrians and Bicyclists (Section 11.3).
4. Assessing Pedestrian and Bicyclist Crash Risks and Volumes (Section 11.4).
5. Traffic Control Devices and Treatments for Pedestrians and Bicyclists (Section 11.5).

11.1 Provision of Access and Design for Pedestrians and Bicyclists

In general, it is preferable to provide people walking or bicycling their own facility to operate outside the path of motorized traffic—sidewalks, shared use paths or designated bike lanes. Section 5.1.3 discusses the provision of pedestrian facilities based on context and Section 3.3.1 identifies the appropriate bikeway type based on relevant criteria, such as the design user, land use context, operating speed, and motor vehicle volume. The following section describes accessible and geometric design for pedestrian and bicycle facilities at rail crossings.

11.1.1. Accessible Design at Rail Crossings

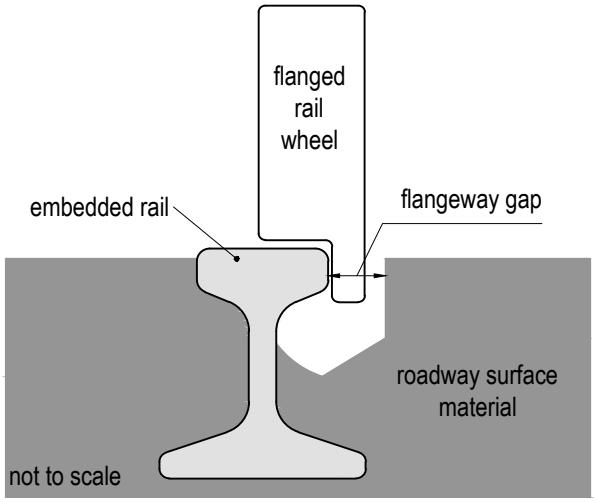
All crossing surfaces, traffic control devices, and any additional treatments provided shall meet applicable accessibility guidelines. The following is a summary of accessibility guidelines detailed in Chapter R3 of the PROWAG.

Pedestrian Access Route and Accessible Ramps

Pedestrian access route widths, grades, cross slopes, and surface treatments across at-grade rail crossings should follow the same design requirements discussed throughout this guide, and at a minimum shall be compliant with ADA accessibility guidelines. A curb ramp may be necessary if the at-grade crossing and the pedestrian access route are at different elevations. The design of the pedestrian access route and curb ramps as described in Chapter 4 apply at rail crossing locations.

As shown in Figure 11-1, flangeway gaps shall be a maximum of 2.5 inches on non-freight rail track and 3 inches on freight rail track. To minimize hazards posed by the flangeway gap, crossings should be as close to 90 degrees as possible (see Section 11.1.2).

Figure 11-1: Illustration of a Rail and Flangeway Gap



Detectable Warnings

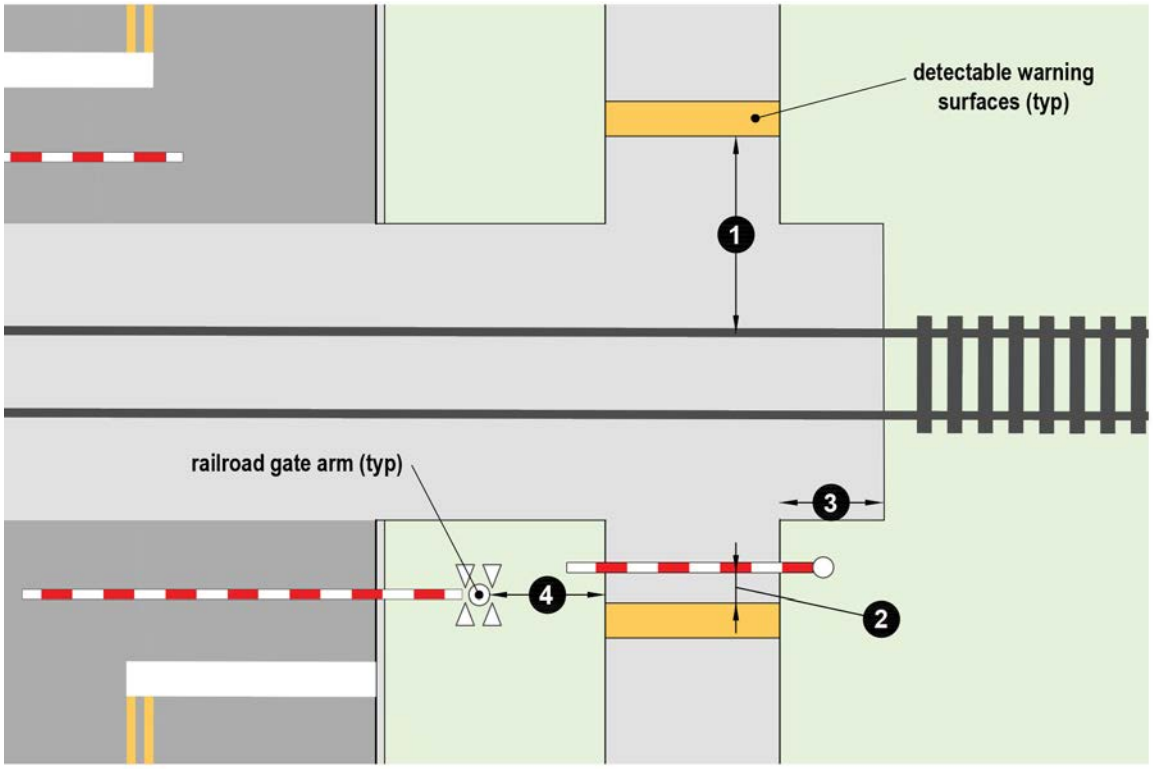
Detectable warning surfaces are required at approaches of all crossings where a sidewalk or shared use path is provided and at locations where a shoulder is intended for pedestrian travel (PROWAG R208.1). Bicycle lanes and separated bike lanes should not include detectable warning surfaces, as they are only intended for bicycle travel.

The detectable warning surface shall be placed so that the edge nearest the rail crossing is 6-15

ft. from the nearest rail. If a gate is present, the detectable warning surface should be located a minimum of 2 ft. from the projection of any gates which extend across the path (placed on the side of the gate opposite the tracks). See Figure 11-2.

Detectable warning surfaces shall be a minimum of 24 inches deep in the direction of pedestrian travel and shall extend the full width of any area in the pedestrian way where there is a level transition between the pedestrian way and the tracks. Where the distance between the centerlines of two tracks exceeds 38 ft., additional detectable warnings designating the limits of a pedestrian crossing island (which shall be minimum length of 6 ft.) should be used at sidewalk or path grade crossings.

Figure 11-2: Placement of Detectable Warnings



1. Nearest edge of detectable warning surfaces shall be placed 6 ft. minimum to 15 ft. maximum from the nearest rail. For skewed railways, in no instance shall the detectable warning be closer than 6 ft. measured perpendicular to the nearest rail.
2. When pedestrian gates are provided, detectable warning surfaces shall be placed on the side of the gates opposite the rail, 2 ft. from the approaching side of the gate arm. This criteria governs over Note 1.
3. Crossing surface should extend 2' minimum past the outside edge of walk or shared use path.
4. Ensure that gate arm counterweight does not overlap with sidewalk when gate arm is extended.

11.1.2. Geometric Design for Rail Crossings

Railroad and streetcar tracks that interface with pedestrian and bicycle facilities can be hazardous to non-motorized users. The following design considerations are important for pedestrian and bicycle facilities located near tracks:

- Design the crossing of the tracks to be between 60 and 90 degrees, with closer to 90 degrees preferred.
- Provide firm, stable, and slip-resistant pavement near tracks.
- Reduce the flangeway width (where practical).
- Provide clear delineation of crossings with pavement markings that indicates to users where they should travel to cross rail tracks at an optimal location and angle.
- Provide warning signs to alert users of the crossing
- Provide adequate sight distances for approaching users to see the crossing ahead.

Generally, there are two configurations of pedestrian and bicycle facilities and rail interfaces: tracks located parallel to the facility, and tracks crossing the facility.

Parallel Tracks

Tracks that are parallel to a pedestrian/bicycle facility may be located in the street (e.g., streetcar) or adjacent to the roadway. These tracks are potentially hazardous to non-motorized users, both when traveling parallel to the track and when crossing over the track.

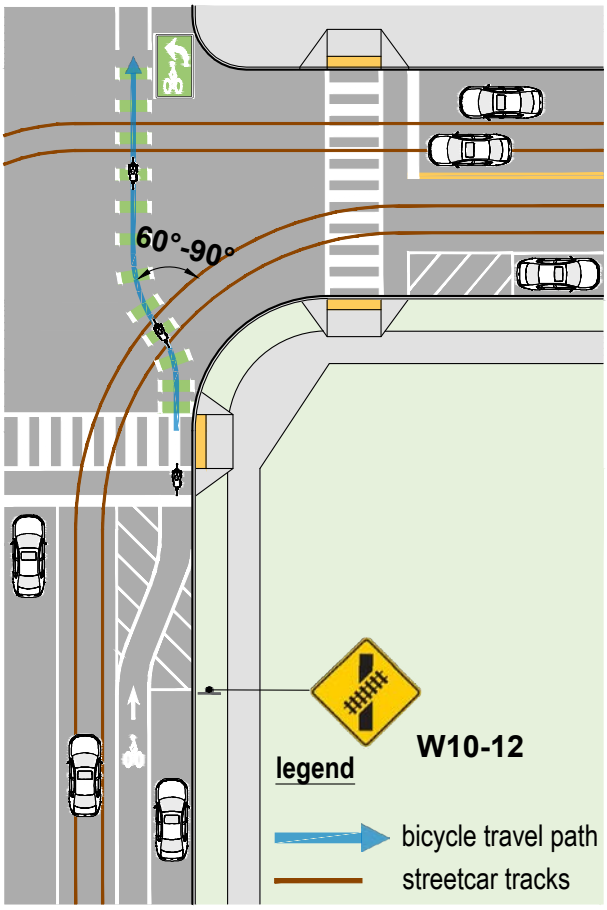
While traveling parallel to the track, a bicyclist's wheel, a wheelchair's caster, or a pedestrian's skate may fall into the flangeway if they travel too close to the track. This may be particularly noteworthy where pedestrian and bicycle facilities are located in the street but can also occur near some shared use paths. In this case, the facility should be clearly delineated, and the distance between the facility and the track should be maximized.

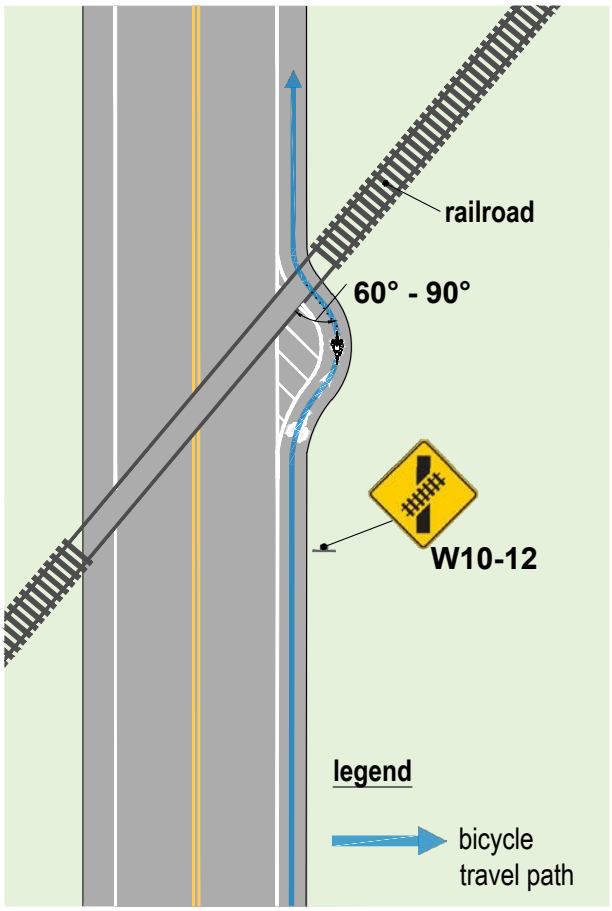
Pedestrians or bicyclists may need to cross parallel tracks when turning onto or off a corridor. When turning, users should be encouraged (through the use of pavement markings) to cross the track at an angle between 60 and 90 degrees. This reduces the chance of a wheel falling into the flangeway and the chance of a user slipping on the rail. Figure 11-3 shows the design of a bikeway crossing parallel tracks.

Crossing Tracks

Rail tracks that cross a street typically cross at an angle near 90 degrees which is relatively easy for a pedestrian or bicyclist to cross. Where the crossing angle is skewed, the pedestrian/bicycle facility alignment should be adjusted to cross as close as possible to 90 degrees and should be no less than 60 degrees. Figure 11-3 shows an example of a bikeway alignment altered to cross skewed railroad tracks.

Figure 11-3: Rail Crossing Geometry Examples





11.2 Evaluate Available Sight Distance

Where the crossing of tracks is not controlled by gate arms, Table 11-1[1] provides the necessary sight distance for perpendicular crossings of rail tracks on level ground. Where the clearing sight distance does not meet the values in this table, a crossing does not provide sufficient sight distance and active traffic control devices should be provided.

In non-standard cases, the following formula may be used to calculate a bicycle minimum crossing time from a stop position:

$$G_{min} = t + \frac{1.47v}{2a} + \frac{D+L}{1.47v}$$

Where:

G_{min} = bicycle minimum crossing time (seconds)

t = perception reaction time (assumed 2.0 seconds)

v = attained bicycle crossing speed (assumed 8 mph)

a = bicycle acceleration (assumed 2.5 ft./second^2)

D = crossing distance from stop, assumed to be 10 ft prior to centerline of nearest set of tracks to 10 ft past centerline of furthest set of tracks

L = length of bicycle (assumed 6 ft.)

The assumed values for the above variables may be adjusted based on site conditions and engineering judgement.

Table 11-1: Clearing Sight Distance from Stop Position

Clearing Sight Distance from Stop Position (ft) *						
	Crossing of 1 Track		Crossing 2 Tracks		Crossing 3 Tracks	
Train Speed (mph)	Pedestrian[1]	Bicyclist[2]	Pedestrian[1]	Bicyclist[2]	Pedestrian[1]	Bicyclist[2]
10	120	100	180	120	240	140
20	230	200	360	240	480	270
25	290	250	450	290	600	340
30	350	290	530	350	720	410
40	460	390	710	470	960	540
50	570	490	890	580	1200	670
60	690	580	1060	700	1440	810
70	800	680	1240	810	1680	940
80	910	780	1420	930	1920	1080
90	1030	870	1590	1040	2160	1210

Notes:
* For far-side stops, the rear buffer should be measured from the nearest edge of crosswalk to the rear of the bus when it is stopped in the stopping area.
Walking 3.5 ft per second across tracks 15 ft. apart, with a 2 second reaction time to reach a decision point 10 ft. before the centerline of the first track, and clearing 10 ft. beyond the centerline of the farthest set of tracks.
Bicycling 8 miles per hour across tracks 15 ft. apart, from a stopped position 10 ft. before the centerline of the first track with an acceleration of 2.5 ft. per second, and clearing 10 ft. beyond the centerline of the farthest set of tracks on a bike of 6 ft. length.

Sight distance can also be restricted at locations with multiple tracks where a stopped train blocks the view of another approaching train. At locations where stopped or slow-moving trains regularly block the view of trains approaching crossings on an adjacent track, the sight distance should be considered restricted and active traffic control devices should be provided.

11.3 Evaluate Primary Control for Pedestrians and Bicyclists

The primary control at a crossing is typically a combination of signs, pavement markings and/or physical barriers that direct the user's attention to the crossing and aid in identifying the appropriate action to take. Treatments vary based on site geometry, traffic volumes and characteristics (of non-motorized users, vehicles, and trains), or site-specific conditions. All traffic control devices and any additional treatments provided shall meet applicable accessibility guidelines.

The first step is to determine if pedestrians and bicyclists can share the traffic control provided for the roadway or if separate primary or supplementary traffic control devices are required. Typically, pedestrians and bicycles may use the roadway signage and signals if the facility is parallel to the roadway and 25 ft. or less from the edge of pavement (measured from the edge of traveled way of the roadway to the outside edge of the separated facility). The primary control may be supplemented by treatments described in Section 11.5.4.

11.3.1. Grade Crossings 25 Ft. or Less from a Parallel Roadway

Where pedestrians and bicyclists share the roadway with motorized traffic or are on a separated facility that is 25 ft. or less from a parallel roadway, any signage or signals applied to the roadway crossing also applies to people walking or bicycling. If pedestrians and bicyclists are provided a separate facility, it is always preferable to maintain that facility through the crossing rather than to redirect the pedestrian or bicyclist facility immediately adjacent to motorized traffic. In instances where automatic gates are installed, a gate or gates shall be provided such that the pedestrian, bicycle, and roadway facilities are all controlled by a gate arm (see Section 11.5.3).

It is not the intent of this chapter to provide guidance on roadway signage or markings. If it is elected that people walking and biking are to follow the roadway traffic control, the designer should ensure that all traffic control devices required by OMUTCD Chapter 8B are present and visible from the pedestrian and bicycle facilities. Separated facilities should be provided their own pavement markings (if used), but additional signage and/or signals may not be necessary unless the traffic control applied to the roadway is not visible to people on the separated facility. The primary control may be supplemented by treatments described in Section 11.5.4.

Considerations for Two-Way Separated Bicycle Lanes

Although two-way separated bicycle lanes are always within 25 ft. or less of the roadway, one direction of travel on the bike lane will be opposing the direction of the nearest roadway travel

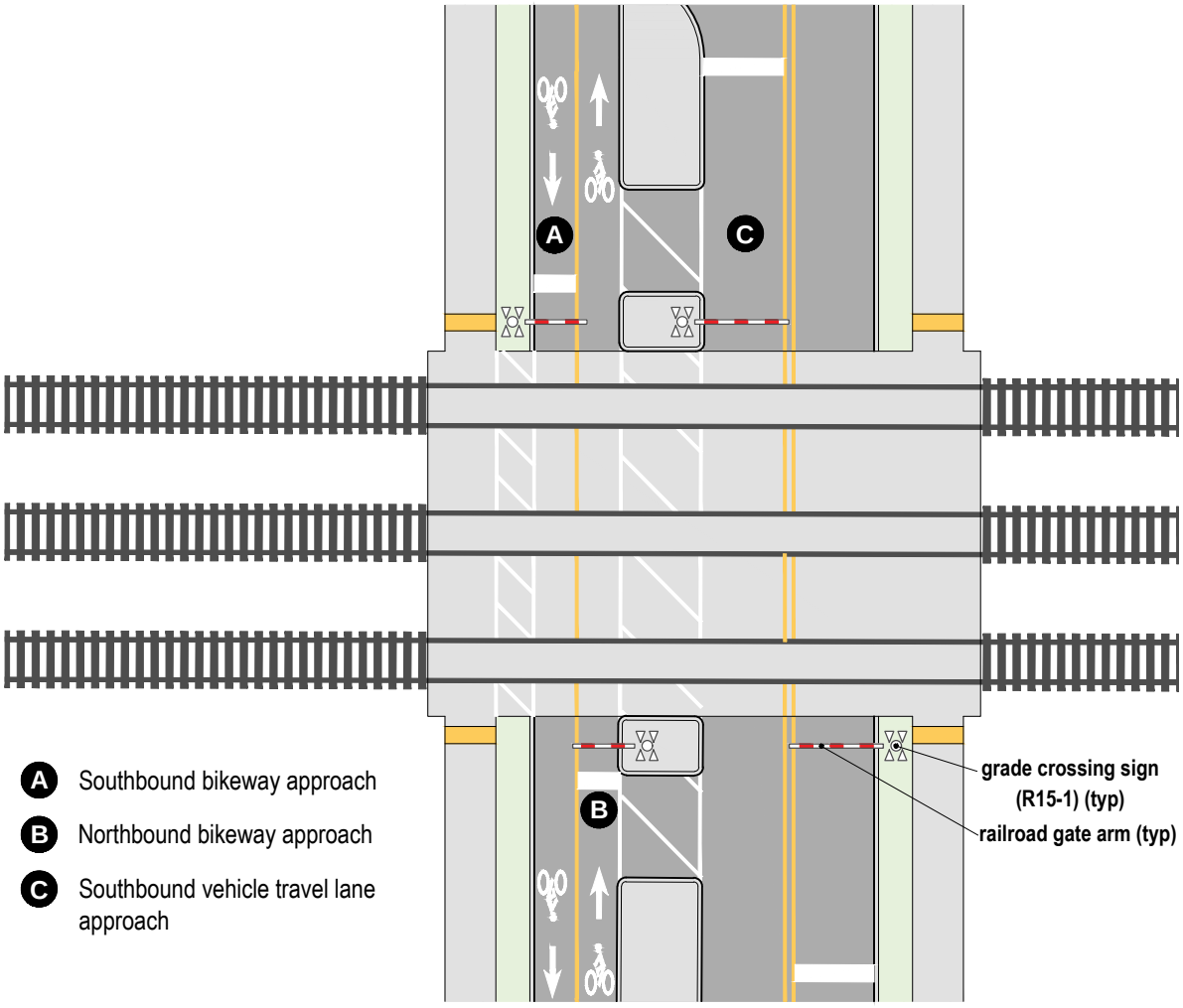
lane. The following discusses traffic control placement and gate arm design for two-way separated bicycle lanes.

Sign Placement for Two-Way Separated Bicycle Lanes

Regulatory and warning signage must be provided for each bicycle approach. Refer to Figure 11-4 for reference on the preferable sign placements for a two-way bike lane.

- Signage for bikeway approach **A** and roadway approach **C** may be combined. It is preferable to place signage to the right of the bikeway. Depending on site conditions and roadway width, it may be appropriate to place signage within the buffer area if buffer widths are sufficient to accommodate signage while meeting shy distances.
- When a raised buffer is used and is sufficiently wide to accommodate signage and shy distances, railroad signage for bikeway approach **B** should be placed to the right of the bikeway and within the buffer. Where narrow buffers exist, signage may be placed to the left of the bikeway.

Figure 11-4: Two-Way Separated Bike Lane Rail Crossing



Automatic Gates for Two-Way Separated Bicycle Lanes

If automatic gates are used on a two-way separated bike lane, a gate arm shall be provided for each approach and should extend to cover the entire width of the approach. A centerline raised median or flexible delineators may be used to prevent bicyclists from bypassing the gate.

Where the gate arm for the bike lane and roadway is combined, the gate arm should extend across the entire width of the bike lane. In these instances, the gate should be located far enough from the nearest rail to accommodate a bicyclist with a trailer who may be trapped between the gate and rails.

11.3.2. Grade Crossings Greater Than 25 Ft. from a Parallel Roadway

At locations where sidewalks, separated bike lanes, or shared use paths are greater than 25 ft. away from a parallel roadway—or where the roadway traffic control is not visible to users of these facilities—separate traffic control devices must be provided for pedestrians and bicyclists in accordance with OMUTCD Chapter 8D. This is typical for grade crossings with shared use paths that have their own alignment independent from a roadway.

Passive Traffic Control

Traffic control at passive crossings consists of signing and pavement markings that generally provide static messaging. At a minimum, a CROSSBUCK sign (R15-1) and a STOP sign[2] (R1-1) are required at all passive crossings unless the crossing has been declared exempt as defined in the Ohio Revised Code. Designers should also review signing and marking treatments that may be required in addition to the primary traffic control devices discussed in Section 11.5.1.

Active Traffic Control

Active traffic control gives visual and audible warning of the approach of a train. Active devices require power service and are activated by the train, which means users will only interact with them when a train is present. All active traffic control devices at rail crossings include flashing-light signals with an audible warning and a CROSSBUCK sign (R15-1). Designers should also review signing and marking treatments that may be required in addition to the primary traffic control devices discussed in Section 11.5.1. See Section 11.5.2 for guidance for locations that include Accessible Pedestrian Signal (APS).

Where rail operation frequency is more than 4 trains per day, train operating speeds increase beyond 35 mph, or sight distance (as described in Section 11.2) is restricted, active traffic control devices should be considered for at-grade pedestrian and bicyclist rail crossings. It may also be desirable to include supplemental traffic control devices (see Section 11.5.4).

In certain conditions, automatic gates are also provided at rail crossing. For the design and implementation of automatic gates, see Section 11.5.3. Flashing signals with automatic gates should be installed in any of the following cases:

- Any crossing with train operating speeds above 79 mph.

- Any crossing with train operating speeds 35 mph or greater where an engineering study or diagnostic review has determined that the sight distance is not sufficient for pedestrians and bicyclists to complete their crossing prior to the arrival of the train at the crossing.
- Any crossing with train operating speeds below 79 mph and either of the following conditions exist:
  - An engineering study or diagnostic review determines pedestrians and bicyclists are exhibiting risky crossing behavior (see "Risky Behavior or Crash History" in Section 11.4).
  - There is a high volume of pedestrians or bicyclists crossing per hour any peak hour in the week (see "High Pedestrian and Bicycle Volume" in Section 11.4).

11.4 Assessing Pedestrian and Bicyclist Crash Risks and Volumes

In addition to the basic controls previously discussed, it may be desirable to provide additional traffic control devices or treatments at locations which have any of the following conditions present:

- Restricted Sight Distance – see Section 11.2.
- Risky Behavior or Crash History – Risky behavior is defined as the observation of pedestrians or bicyclists:
  - Ignoring traffic control devices or bypassing traffic control devices.
  - Failing to observe approaching trains.
  - Attempting to cross in front of approaching trains, placing the individual at risk of being struck by the train.
  - Crossing through a stopped train by stepping between cars or rolling under a car.
  - Waiting too close to crossing trains.
  - A history of crashes that have the potential to be corrected by engineering measures.

This behavior should be documented through an engineering study or diagnostic review that demonstrates an existing safety problem.

- High Pedestrian and Bicycle Volumes – High pedestrian and bicycle volumes are relative to the surrounding population and land uses. Designers should consider the context of the crossing location. In urban areas, the minimum value might be 60 pedestrians/bicyclists per hour; however, in some suburban or rural contexts, the minimum value may be lower. Crossings near major pedestrian generators such as stadiums, parks, transit or passenger transfer stations, schools, or other activities can create pedestrian and/or bicyclist surges during specific times. Designers should be aware of the influence of these activity-generators and special events when evaluating user volumes and crossing behaviors.
- Quiet Zone – In an area designated as a quiet zone, trains may not sound their horn when approaching a crossing. In these locations, additional treatments should be considered to mitigate the increased risk caused by the absence of a horn.

11.5 Traffic Control Devices and Treatments for Pedestrians and Bicyclists

Other than grade crossing CROSSBUCK signs (R15-1) that are required at all rail crossings, the decision to provide additional traffic control devices is dependent on a variety of factors. The following describes traffic control devices most often used at rail crossings as well as the design and implementation of primary traffic control devices. Figure 11-5 provides guidance for selecting the recommended and optional traffic control devices and treatments to address specific site conditions and train speeds.

11.5.1. Signing and Markings

Stop Lines

Stop lines indicate a location where bicyclists should stop at rail crossings. Stop lines should be provided at all shared use path, shoulder, separated bike lane, and bike lane crossings to ensure bicyclists are waiting outside the dynamic envelop of a train. They should also be used at all locations with a gate to ensure bicyclists stop prior to a gate. Stop lines may extend across the full width of the bikeway and should be:

- 12 inch – 24 inch wide white lines. Although stop lines of 24 inches are most common for roadways, 12 inch lines may be considered on bikeways (see OMUTCD 3B.16).
- Located no less than 15 ft. nor more than 50 ft. in advance of the nearest rail
- Located a minimum of 2 ft. from the projection of any gates which extend across a path, placed prior to the approach to the gate. If stop lines are co-located with roadway stop lines, they should be located a minimum of 8 ft. from the gate (see OMUTCD 8D.04).

Path Delineation

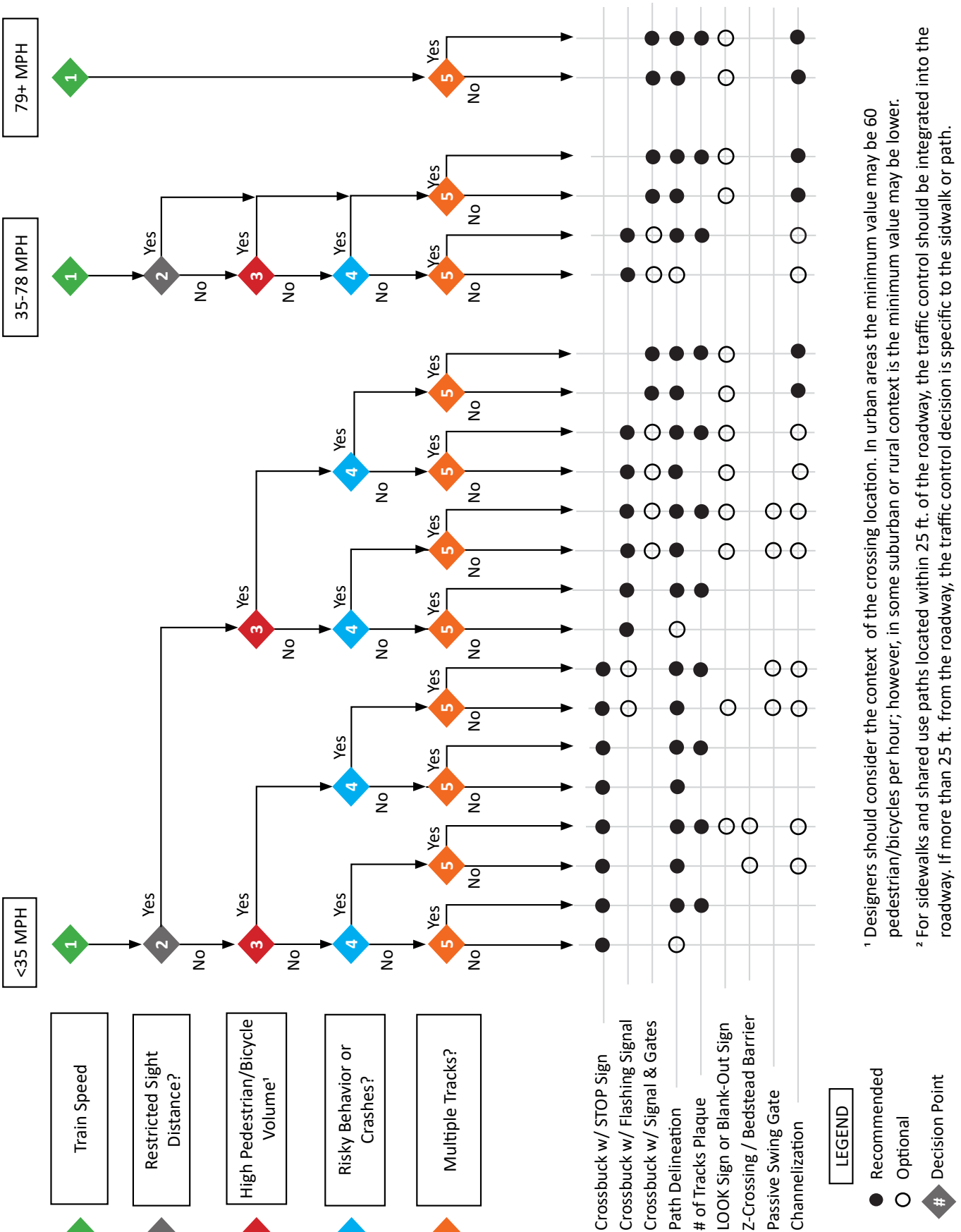
Path delineation defines the path a pedestrian or bicyclist should take to safely and efficiently navigate an at-grade rail crossing. People should not have to make decisions as to the appropriate direction of travel after entering the grade crossing. Due to the irregular shape of the rails, a longitudinal bar or double-bar style crosswalk is not recommended.

Where pedestrians are expected to cross, path delineation should be provided by either or both of the following:

- Pavement markings (minimum 4 inch white edge lines or crosswalks).
  - 6-12 inch lines may be used to add emphasis to the crossing location and assist people with visual disabilities to identify the edge of the path.
- Color/texture differences which provide visual contrast from the surrounding area

Path delineation should be used at any crossing where one or more of the following conditions exist:

Figure 11-5: Decision Tree for Selecting Traffic Control Devices & Treatments for Pedestrian and Bicycle Rail Crossings



¹ Designers should consider the context of the crossing location. In urban areas the minimum value may be 60 pedestrian/bicycles per hour; however, in some suburban or rural context is the minimum value may be lower.

² For sidewalks and shared use paths located within 25 ft. of the roadway, the traffic control should be integrated into the roadway. If more than 25 ft. from the roadway, the traffic control decision is specific to the sidwalk or path.

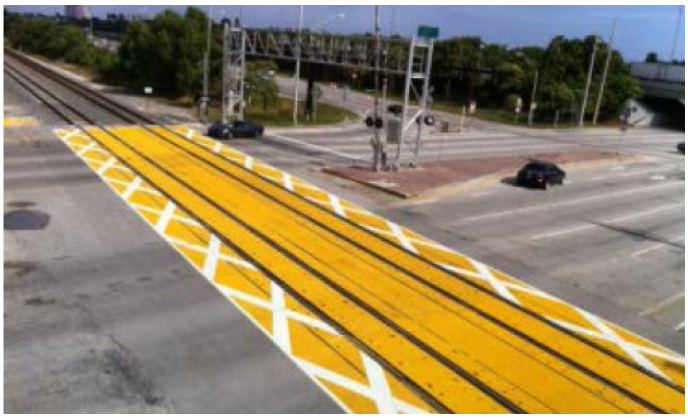
- Crossing length exceeds 40 ft. (such as at skewed crossings).
- Locations with more than 1 track.
- Where the pedestrian or bike path is immediately adjacent to a vehicular traveled way.

Dynamic Envelope Markings

Dynamic envelope markings are a type of pavement marking that identifies the physical boundary of a train as it travels through a crossing. They are recommended at all crossings that include gates where a person may be located between a gate and the tracks. They should be:

- A minimum of 4 inch width white pavement markings.
- Located to create a buffer that is 6 ft. minimum from the nearest rail.

Figure 11-6: Example Dynamic Envelope Markings with Optional Supplemental "Do Not Block Intersection" Markings (Source: Federal Railroad Administration)



Skewed Crossing Sign (W10-12)

A crossing angle of less than 60 degrees from perpendicular is not recommended (see Section 11.1.2). When a crossing angle less than 60 degrees cannot be avoided, a SKEWED CROSSING sign (W10-12) should be used wherever bicyclists must cross tracks at an angle between 30 and 60 degrees from perpendicular, as they have an increased likelihood of a crash due to a wheel being caught in a rail flangeway.

Grade Crossing (CROSSBUCK) Sign (R15-1)

A CROSSBUCK sign (R15-1) is required at all rail grade crossings. The sign should be installed on the right side of facilities, although it may be located to the left side if the facility is using the roadway signage.

Number of Tracks Plaque

A NUMBER OF TRACKS plaque (R15-2P) supplements a CROSSBUCK sign (R15-1) and shall be provided at all crossings where automatic gates are not present and there are two or more tracks at a grade crossing. When automatic gates are present, a NUMBER OF TRACKS Plaque (R15-2P) may still help inform non-motorized users of the crossing distance and avoid leaving them trapped between the gates.

LOOK Sign (R15-8)

The LOOK sign (R15-8) should be mounted as a supplemental plaque at all locations where trains operate in two directions and where one of the following conditions occurs:

- An engineering study or diagnostic review has determined that the sight distance is not sufficient for pedestrians and bicyclists to complete their crossing prior to the arrival of the train at the crossing (see Section 11.2).
- An engineering study or diagnostic review determines that pedestrians and bicyclists are exhibiting risky crossing behavior (see Section 11.4, "Risky Behavior or Crash History").
- Locations with passive pedestrian swing gates.
- There are not high pedestrian volumes (see Section 11.4, "High Pedestrian and Bicycle Volumes").

The LOOK Sign (R15-8) should not be used where blank out signs or automatic gates are present.

Blank-Out Warning Sign

A Blank-Out Warning sign, such as the LIGHT RAIL TRANSIT APPROACHING-Activated Blank-Out Warning Sign (W10-7), may be posted at locations where it is desired to provide additional emphasis in place of the LOOK Sign (R15-8) or at locations with multiple tracks where stopped or slow-moving trains block the view of trains approaching on an adjacent track. Other example messages for the Blank-Out sign include TRAIN APPROACHING "LOOK" or SECOND TRAIN—LOOK LEFT/RIGHT messages.

Blank-Out Warning signs may also be used when a movement is only prohibited when a train or streetcar is present, such as a turning movement that crosses tracks.

11.5.2. Flashing-Light Signals

Flashing-Light Signals with Audible Warning Device

Flashing light signals consist of two light units arranged horizontally that flash in an alternating pattern. They may be mounted on assemblies next to the roadway or path, overhead, or both, based on site visibility. Flashing-lights shall be accompanied by a CROSSBUCK sign (R15-1) on the mounting assembly and an audible warning device.

Pedestrian Signals and Audible Pedestrian Signals

At crossing locations controlled by highway traffic signals, pedestrian signals are required. All pedestrian at-grade crossings with active controls must provide supplemental bells or other audible warning devices. Locations controlled by traffic signals which include Accessible Pedestrian Signal (APS) equipment do not require supplemental bells or audible devices as they may diminish the effectiveness of the APS equipment.

11.5.3. Automatic Gates

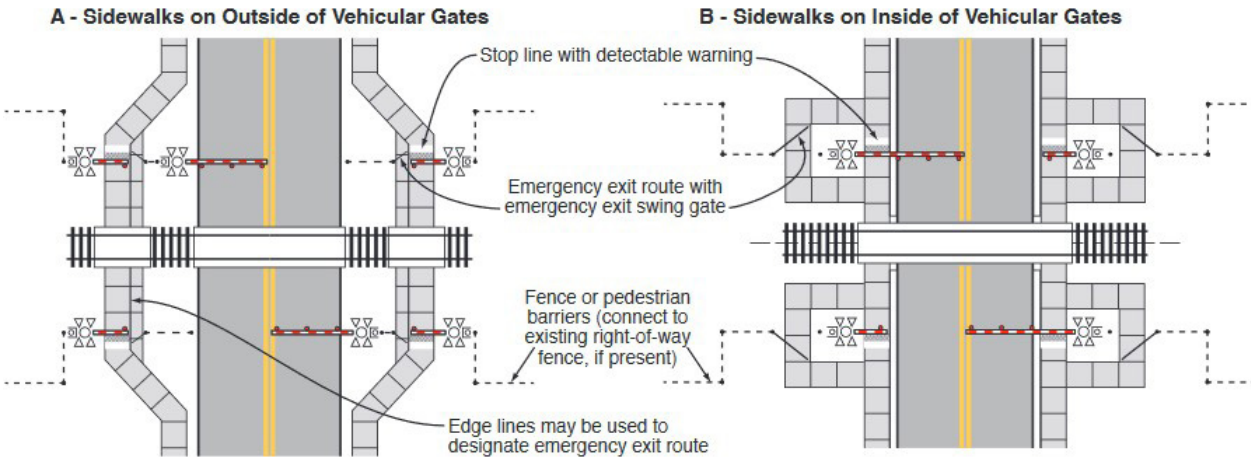
Automatic gates lower when a train is approaching to create a physical barrier between the pedestrian or bicyclist and the tracks. Automatic gates are installed in addition to flashing-light signals in order to enhance visibility and inform pedestrians and bicyclists when it is safe to cross. If a separate pedestrian or shared use path gate is provided, the need for a separate CROSSBUCK sign,

audible device, and flashing-light signal should be determined based on site-specific conditions such as the proximity of the sidewalk or shared use path to the roadway grade crossing devices, see Section 11.3.

Automatic gate arms shall extend the full width of the sidewalk or shared use path. The sidewalk or shared use path gate may be combined with adjacent vehicular gates (if pedestrians and bicyclists are following the roadway traffic control), or a separate gate may be provided as shown in Figures 8C-5 and 8C-6 of the OMUTCD, and Figure 11-7 below. There should be a minimum of 2 ft. between the edge of sidewalk or path and any protrusions from the gate arm and counterweights while in its raised position or any portion of the flashing-light signal assembly.

Where automatic gates are installed, channelizing fence and gate skirts may be used to prevent bicyclist and pedestrians from bypassing the gates. A clear zone should be provided between the train's dynamic envelope and the pedestrian gates that is a sufficient width for the anticipated users, including bicyclists with trailers. The dynamic envelope of the train should be marked. An emergency exit swing gate must allow pedestrians to exit the refuge area so that they do not become trapped on the trackway when the automated gates are activated. This will require the use of a separate gate arm for sidewalks and shared use paths. Each of these treatments are discussed in the subsequent sections.

Figure 11-7: Automatic Gates - Separate from Vehicular Gates (Left) & Combined with Vehicular Gates (Right)


A - Sidewalks on Outside of Vehicular Gates
B - Sidewalks on Inside of Vehicular Gates
Stop line with detectable warning
Emergency exit route with emergency exit swing gate
Fence or pedestrian barriers (connect to existing right-of-way fence, if present)
Edge lines may be used to designate emergency exit route

Channelizing Fencing

Fencing may be used to discourage pedestrians from crossing tracks at random by preventing them from bypassing the gate. Fencing should extend parallel to the tracks at least 50-100 ft. back from designated pedestrian crossings to direct pedestrians to the crossing. Where fencing is used, the height should be a maximum of 3.5 ft. within 100 ft. of the crossing to avoid restricting sight distances. Alternatives to fencing less likely to impede sight distance include bollards, short posts with chains, or low landscaping.

Gate Skirts

Crossing gate skirts may be constructed across pedestrian facilities by attaching a horizontal hanging bar to the gate arm (see Figure 11-8) and have been shown to be effective at reducing the likelihood that pedestrians, in particular children, will violate a lowered crossing gate. Gate skirts should be provided where pedestrian traffic is likely.

Entrapment and Emergency Swing Gates

Individual users on bikes or walking will require a broad range of times to complete a crossing. As such, it may not be possible or practical to time the gate arms so that all users can clear the tracks before the arms lower. This may leave some slower-moving users trapped between the tracks and the gate as a train approaches. A refuge area clear of obstructions should be provided between the train's dynamic envelope and the pedestrian gates that is of sufficient width for the anticipated users, including bicyclists. Gates located a minimum of 14 ft. from the nearest rail would accommodate a typical bicyclist, and a minimum of 18 ft. from the nearest rail to accommodate a bicyclist with a trailer. These minimums assume a dynamic envelope of 6 ft. and should be enlarged if directed by the rail operator. The dynamic envelope should be marked so that any entrapped users are aware of what space may be safely occupied.

In locations where entrapment is possible, an emergency swing gate (see Figure 11-9) shall be provided that allows users to exit the refuge area. Emergency swing gates shall open away from the tracks and should have a latch that only permits the gate to be opened from the track side of the gate. Swing gates shall automatically return to the closed position after each use.

Figure 11-8: Automatic Gate Arm with Gate Skirt

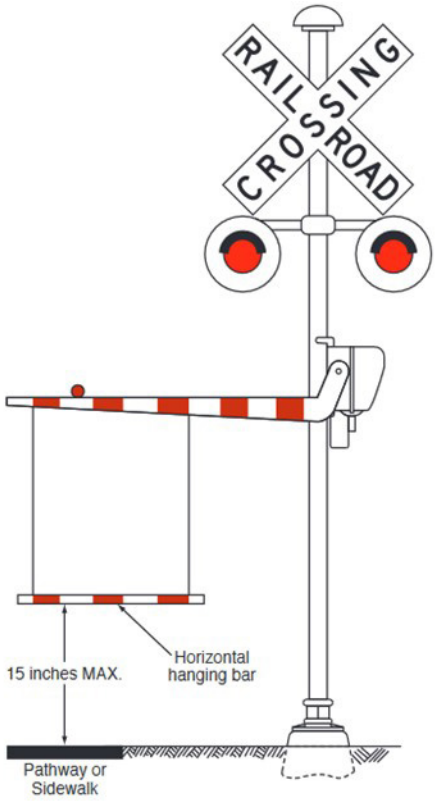


Figure 11-9: Automatic Gate for Pedestrian Facilities with an Emergency Swing Gate (Source: Los Angeles County Metropolitan Transportation Authority)

The design of the emergency swing gate shall permit the passage of wheelchairs, power-assisted mobility devices, and bicycles (where allowed). The design should permit bicyclists to traverse the gate by dismounting and walking the bicycle through the gated area. If the emergency swing gate is at a different elevation than a bike lane (for example, the bike lane is street level and the gate is on a sidewalk), then a ramp should be provided to allow bicyclists to access the emergency swing gate. Swing gates shall be designed in compliance with current ADA requirements. The gate should be retroreflective.

11.5.4. Supplemental Treatments

The following supplemental treatments are optional treatments that may support the primary and other required traffic control devices when certain conditions are present.

Z-Crossing or Bedstead Barrier Channelization

Z-crossing or Bedstead Barrier channelization requires approaching pedestrians and bicyclists to deviate from their approach path in advance of the crossing. They may be considered for use at crossings where:

- There are not high pedestrian or bicyclist volumes (see Section 11.4, “High Pedestrian and Bicycle Volumes”).
- Sight distance meets requirements for pedestrians and bicyclists (see Section 11.2).
- An engineering study or diagnostic review determines people exhibit risky crossing behavior (see Section 11.4, “Risky Behavior or Crash History”).
- Location does not allow for bicyclists or pedestrians to easily bypass the Z-crossing or Bedstead Barrier.

The design of these crossings needs to permit the passage of wheelchairs and power-assisted mobility devices. The design should also permit bicyclists to traverse the barriers at low speed without dismounting and accommodate the physical lengths of longer bicycles (e.g., cargo bikes, bikes with trailers).

The use of Bedstead Barriers should be limited to locations with a documented risky behavior or crash problem that is caused by bicyclists not stopping at railroad crossing. Bedstead Barriers present a fixed object safety hazard to bicyclists and can impede passage for bicyclists and pedestrians exiting a railroad crossing by slowing the exit if/when groups cross, potentially trapping people within the crossing area.

Pedestrian Swing Gates

Pedestrian swing gates are movable barriers that pedestrians and bicyclists must open manually to cross the tracks. The pedestrian swing gate differs from the emergency swing gate discussed in Section 11.5.3 because pedestrian swing gates are opened to begin a rail crossing whereas emergency swing gates are opened to complete a rail crossing and prevent entrapment. Pedestrian swing gates may be used where:

- There are high pedestrian or bicyclist volumes (see Section 11.4, "High Pedestrian and Bicycle Volumes").
- Sight distance does not meet requirements for pedestrians and bicyclists (see Section 11.2).
- An engineering study or diagnostic review determines people exhibit risky crossing behavior (see Section 11.4, "Risky Behavior or Crash History").
- Location does not allow for bicyclists or pedestrians to easily bypass the swing gate.

Pedestrian swing gates shall open away from the tracks and should be able to be easily opened from either side of the gate. Swing gates shall automatically return to the closed position after each use.

The design of the pedestrian swing gate shall permit the passage of wheelchairs, power-assisted mobility devices, and bicycles (where allowed). The design should permit bicyclists to traverse the gate by dismounting and walking the bicycle through the gated area. Swing gates shall be designed in compliance with current ADA requirements, and a detectable warning shall be placed in advance of the gate (see Section 11.1.1). The gate should be retroreflective.

Since swing gates present a fixed object safety hazard to bicyclists, their use should be limited to locations with a documented risky behavior or crash problem that is caused by bicyclists or pedestrians not stopping at railroad crossings. The LOOK sign (R15-8) should be mounted as a supplemental plaque at all locations where trains operate in two directions and a pedestrian swing gate is used.

Channelization

Channelization strategies may be used to guide people to the rail crossing and encourage them to take the desired path through the crossing. It can consist of rough surfaces designed to be unwalkable/rideable, fences, or other similar barriers. Where fencing or barriers are used, the ends should be retro-reflectorized and sufficient lighting should be provided to ensure the crossing area is visible to approaching bicyclists and pedestrians to reduce the potential for a crash.

Supplemental Illumination

Supplemental illumination should be considered to enhance visibility of the crossing and traffic control treatments where one or more of the following conditions occur:

- Road users have trouble seeing trains or traffic control devices during hours of darkness
- A substantial amount of railroad operations occur at night (greater than 4 trains per evening)
- Locations with frequent operation of low speed trains (greater than 4 trains per day)
- Grade crossings are blocked for extended periods of time at night (such as near switching yards)
- A crash history indicating that people fail to detect trains or traffic control devices at night
- Locations with restricted sight distance to the crossing on the approach
- Locations where long dark trains, such as unit coal trains, operate at night

11.6 Additional Resources

The following resources provide information about the design of rail crossings to accommodate people walking and biking:

- Ohio Manual of Uniform Traffic Control Devices (OMUTCD), Part 8. Ohio Department of Transportation, Columbus, Ohio, 2012.
- Traffic Engineering Manual (TEM), Part 8. Ohio Department of Transportation, Columbus, Ohio.
- Highway-Rail Crossing Handbook, 3rd Edition. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2019.
- Engineering Design for Pedestrian Safety at Highway-Rail Grade Crossings. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2016.
- Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG), Chapter R3. United States Access Board, Washington DC, 2011.

Chapter 11 Endnotes

1 This table incorporates the values from Table 41 in the Railroad-Highway Grade Crossing Handbook, Revised 2nd Edition, 2007.

2 A STOP sign is required by ORC 4511.61, which was revised after the publication of the 2012 OMUTCD. See Traffic Engineering Manual (TEM) Section 801-2.

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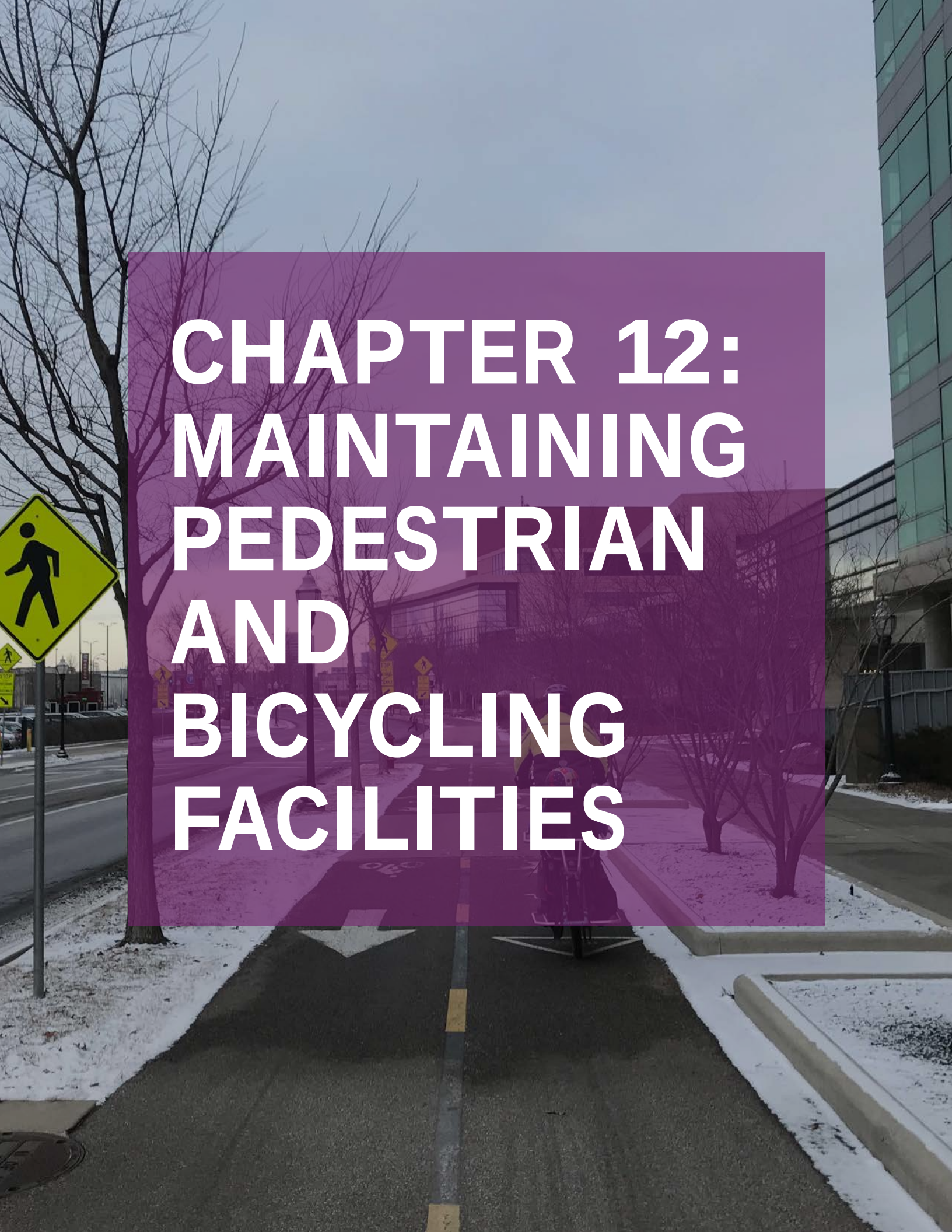


CHAPTER 12: MAINTAINING PEDESTRIAN AND BICYCLING FACILITIES

Chapter 12: Maintaining Pedestrian and Bicycling Facilities

12.1 General

This chapter describes approaches to maintaining safe, comfortable, and accessible walkways and bikeways year-round through routine asset management and seasonal maintenance. Communities generally maintain on-street bikeways as part of routine street maintenance. However, sidewalks, separated bike lanes, and shared use paths require dedicated maintenance activities and, in some cases, equipment.

12.2 Management Approaches

Non-winter maintenance is broadly placed into two categories: infrastructure repair and year-round maintenance. Both types of maintenance should be supported by a robust inspection and compliance program. The Roadway Infrastructure Maintenance Responsibility Manual (RIMR) establishes all roadway infrastructure maintenance responsibilities throughout the state. In addition, WBO's Maintenance Overview specifically summarizes the maintenance responsibility and activities for pedestrian and bicycle facilities as well as local and national sidewalk maintenance case studies. In addition, the report summarizes maintenance funding opportunities available to local governments.

12.2.1. Inspections/rating system

Routine inspections and rating systems track pavement conditions of shared use paths, separated bike lanes, and sidewalks. The goal of a rating system is to build a program of surface maintenance which extends facility life, delaying expensive reconstruction projects and thereby saving money over the long run. No matter the surface of the facility (asphalt, concrete, gravel), these types of inspections should be completed on an annual or biennial basis for shared use paths and separated bike lanes, and every three to 10 years for sidewalks.

Inspection programs for sidewalks are described in detail in Chapter 4 of the Federal Highway Administration's (FHWA) Guide for Maintaining Pedestrian Facilities for Enhanced Safety.[1] This includes inspection criteria, ADA requirements, and types of inspection programs. Inspection and maintenance should be coordinated with ODOT's Transportation Asset Management Plan. See ODOT's Pavement Condition Rating System Manual.

12.3 Types of Maintenance

Year-round maintenance activities include pavement marking and sign repair, pavement preservation, vegetation management, and sweeping.

12.3.1. Signal, Signing, and Pavement Markings,

Signing and pavement markings on and along pedestrian and bicycle facilities should be maintained to be clear and legible allowing these facilities to function safely and comfortably. Similarly, traffic signals on and along pedestrian and bicycle facilities shall be inspected a minimum of one time annually to ensure reliable function and identify signals and equipment to be replaced before failure. TEM Section 260, 360, and 460 provide inspection and maintenance guidance for signing, pavement markings, and signals respectively for roadways, which can also be applied to separated bike lanes and shared use paths. Facilities should be inspected per this guidance and repaired or replaced when necessary.

12.3.2. Street Buffer Treatments and Sidewalk Buffer Amenities

Vertical objects placed within a separated bicycle lane street buffer may be struck by motor vehicles and require regular replacement. Maintenance and operation crews should plan on replacing vertical objects placed in the buffer zone, refreshing pavement markings, and trimming any adjacent vegetation on a regular basis. If vertical objects are struck with significant regularity, adjustments to the design should be considered.

Other elements along walkways and bikeways that are provided to address pedestrian and bicyclist safety and comfort, such as lighting, benches, trash receptacles, etc., should also be inspected on a regular basis to ensure they are in good working condition, and when appropriate these elements should be repaired and/or replaced. Small plaques may be affixed to these elements, or signs added at trailheads, providing a method for the public to report damaged amenities.

12.3.3. Asphalt Paths and Separated Bike Lanes

Asphalt is the most common surface type for shared use paths and separated bike lanes. As discussed in Section 5.3.9, shared use paths are typically designed to accommodate less loading than a roadway; however, as pavement section thickness decreases, the susceptibility to cracking, settlement, and root uplift typically increases. In northern climates like Ohio, these facilities should be built at least 6 inches thick, with an additional 4 inches to 6 inches of subgrade underneath. Eventually all bicycle facilities must be reconstructed, but with proper maintenance techniques, it can be delayed up to 40 years. To extend the life of the pavement and maintain a smooth rideable surface, a regular maintenance schedule such as the one shown in Figure 12-1 should be adopted. Table 12-1 illustrates the relative costs of maintaining asphalt bicycling facilities.

Figure 12-1: Example shared use path maintenance schedule for a 38-year design life

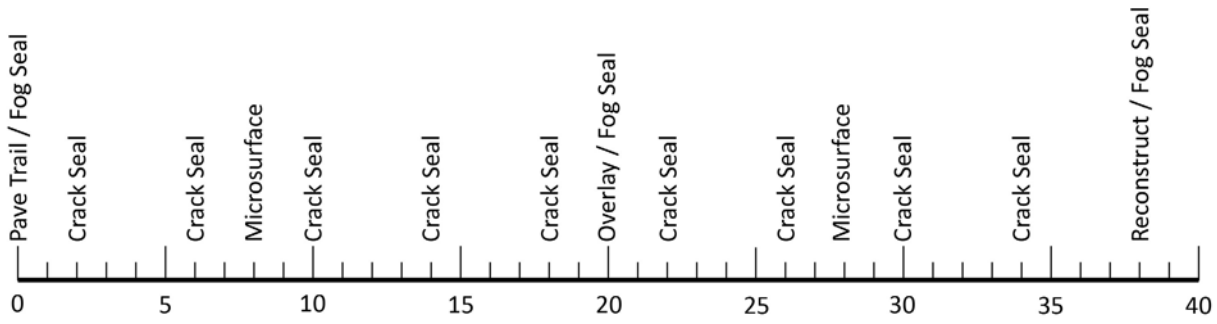


Table 12-1: Construction costs for typical asphalt pavement surfaces

Activity		Relative Cost/Mile
Maintenance	Fog Sealing	$
	Crack Sealing	$
	Microsurfacing	$$
	Asphalt Overlay	$$
Reconstruction	Reconstruction	$$$

Relative costs: $ = Thousands, $$ = Tens of Thousands, $$$ = Hundreds of Thousands

Crack sealing

Crack sealing extends the life of asphalt by diverting water from seeping through cracks that leads to erosion of the base layer of the pavement. The process of crack sealing includes blowing out debris with compressed air, heating the crack face with a lance, and then filling it with sealant. Sealants should be rubberized to seal the crack while staying flexible with the pavement's movement. Crack sealing should be applied within the first five years of pavement construction to achieve the maximum benefit, and then reapplied as needed thereafter. A layer of paper placed on top of crack sealing allows wheeled and foot traffic to continue after its application.

Figure 12-2: A shared use path that has been crack sealed

Fog sealing

Fog sealing is a thin layer of liquid oil applied to asphalt pavement that enriches the surface and prevents further deterioration. Fog seals can also seal minor cracks. Treatment typically lasts for three to five years and is the least expensive type of pavement maintenance activity. Fog sealing may be done in combination with crack sealing and pavement patching. The pavement should be cleaned of debris, rocks, and weeds in advance of application. Overhanging trees may also be trimmed to provide access for the oil distributor trucks. Fog seal applications should be monitored to ensure they don't create a surface that is slick for bicyclists.

Microsurfacing

Microsurfacing is mix of oil, finely crushed stone, filler (e.g., Portland cement), and chemical additives. While it can be four to eight times as expensive as fog sealing, it lasts longer and provides an improved element of traction that fog sealing does not.

Asphalt overlay

In instances where the pavement base materials are still intact and undamaged, asphalt can be overlaid on top of the existing asphalt. If existing asphalt is damaged on the surface but intact farther down, the top layer may be milled down (or scarified) before a new layer of asphalt is placed. The purpose of milling is to provide a stable asphalt base so that existing cracks do not reappear through the new layer. Besides reconstruction, asphalt overlays are the most expensive type of surface maintenance. However, it is still an effective way to extend the life of a shared use paths and separated bike lanes in the same way it's used for roadway maintenance, since all of the existing material does not have to be removed or recycled, and a new base layer of aggregate does not have to be laid.

Figure 12-3: Fog sealing being applied to a side path. (Photo credit: City of Rochester, MN)

Figure 12-4: A shared use path with fresh microsurfacing. (Photo credit: Three Rivers Park District)

Figure 12-5: An asphalt overlay on top of an existing asphalt path, which previously had a deteriorated

Reconstruction

Shared use path and separated bike lane reconstruction is the process of entirely removing and/or recycling an existing pavement that has deteriorated to the point where it can no longer be maintained

Spot Repairs

If vertical surface discontinuities develop in the pavement, the pavement should be repaired appropriate to provide a smooth walking and biking surface:

- If they are less than 0.5 inches in depth, the surface may be beveled with a slope not steeper than 50 percent. The bevel shall be applied across the entire vertical surface.
- If they are more than 0.5 inches in depth, they may cause a ripping hazard and should be reconstructed to smooth out the surface.

12.3.4. Concrete Paths

Where concrete is used for shared use paths, FHWA's Guide for Maintaining Pedestrian Facilities for Enhanced Safety[2] provides a comprehensive discussion for maintenance. The guide includes information on surfacing issues, grades, cross slopes, curb ramps, concrete patching, wedging, grinding, horizontal cutting, slab-jacking, and panel replacement.

12.3.5. Vegetation Management

Maintenance of vegetation next to sidewalks, shared use paths, and separated bike lanes is necessary both above and below ground to ensure the functionality and long-term condition of these paths are maintained.

Above ground mowing and pruning

Routine trimming, mowing, and pruning of vegetation contributes to the aesthetics and user safety. These activities should be performed on a regular basis to keep sight lines clear and the areas free from obstructions. Agencies should also be prepared to respond to specific complaints of low-hanging branches or downed trees as needed. When performing maintenance activities, the area should generally be cleared for 2 ft. on each side, as well as a height of 10 ft. clearance.

Trees that are diseased can affect the safety of facility users—if they fall they may interfere with sight distances, clearance, or lighting. If they have the potential to fall on a walkway or bikeway, they should be removed. If they don't, they should remain undisturbed to preserve natural aesthetics and habitat for wildlife.

Below ground roots

Below ground tree and shrub roots may affect the pavement surface due to their proximity or size. In the case of asphalt pavement, roots can cause the surface to raise-up and create abrupt bumps and ripples that affect ADA compliance for pedestrians, serve as tripping hazards, and can create severe rideability issues for wheeled users. A root barrier can be used to help prevent root uplift,

which can be installed as part of the original installation or as part of pavement spot repairs. A certified arborist should be consulted regarding tree proximity and health before root barriers are installed. Walkways and bikeways can also be routed around vegetation, or trees and shrubs may be removed during the design or maintenance process.

When root uplift does occur, sidewalks are often ground down at the root uplift to remove the surface discontinuity, but asphalt pavement typically needs to be milled and may require reconstruction to correct root uplift issues. Where the installation of root barriers is not desired due to tree health or proximity, another typical treatment for asphalt areas with root uplift damage is to replace the damaged area with pervious pavement surfaces such as rubberized pavement or pervious asphalt. The pervious surfaces will allow stormwater to reach the tree roots and reduce the damaging uplift; however, these areas will still require regular maintenance to correct surface deformations that are likely to continue.

12.3.6. Sweeping

Routine sweeping of walkways and bikeways is necessary in areas with overhanging trees and shrubs to remove leaves which may obscure potholes and other surface irregularities and which when wet or froze become slick and become dangerous to bicyclist ability to stop or control their direction of travel. Where walkways or bikeways intersect with gravel roads or driveways, these locations should be regularly swept to keep the pedestrian and bicycle path free of gravel. It is preferable that paved approaches or aprons be provided to reduce gravel spread and overall maintenance needs where these conditions are present. Bikeways should also be swept immediately following a large storm events and where sand is spread for traction in winter and where facilities meet roads where sand is spread.

Large-scale sweeping efforts are most effective with special sweeping equipment, such as broom attachments for utility vehicles. Broom attachments can also be used for snow during winter maintenance. Sweeping on walkways and bikeways is typically handled by local agency maintenance staff, while sidewalk sweeping is usually carried out by adjacent property owners. Special service districts (or business improvement districts) will sometimes include sweeping services, and coordination with these districts should occur to find local opportunities to maintain specific facilities in their district.

12.4 Winter Maintenance

Winter maintenance activities include before, during, after winter precipitation techniques, equipment, design, and transit stops. Districts and local jurisdictions should develop a snow maintenance plan for the bicycle network to help prioritize which corridors are of higher importance to clear first, for example main routes to transit, work centers, or major destinations. As new bikeways are added to the network, the maintenance plan should be updated to account for the new facilities. The snow maintenance plan should also identify the equipment needed to maintain each bikeway so that the equipment deployment is understood and organized as part of the regular equipment deployment

12.4.1. Schedule

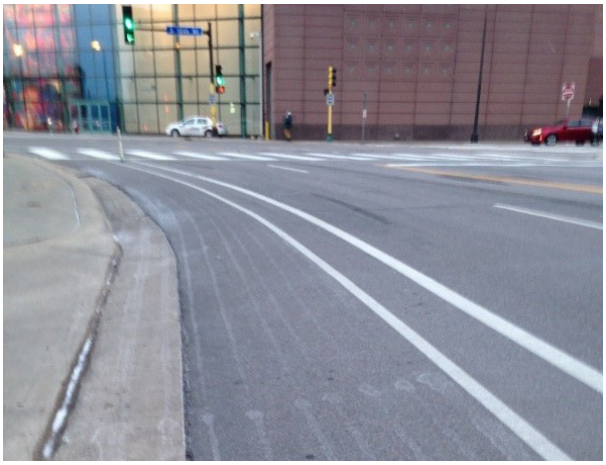
Like for motorists, the safest walking and bicycling surface for pedestrians and bicyclists is bare pavement. Achieving bare pavement may require action before, during, and after winter precipitation.

- **Before:** Pre-treating paths, walkways, or bikeways with salt brine or ice bite will lower the temperature at which liquid freezes, often keeping pavement surfaces wet and reducing the formation of ice.
- **During:** Clearing accumulated precipitation often prevents footsteps and bicycle tires from packing snow onto surfaces.
- **After:** Clearing snow and ice with equipment and spreading material (e.g., sand and salt) speeds melting and improves traction.

Liquid anti-icing mixtures such as salt brine and the beet-based ice bite are often used to pre-treat walkways and bikeways before a winter storm. Pre-treating or anti-icing offers many benefits over de-icing (i.e., applying salt after a snow storm), including faster salt activation and quicker melting, lower melting temperature, better salt penetration, and reduced salt loss due to a lower "bounce and scatter" rate, which saves money and reduces environmental impacts by using less material. Applying too much salt as a winter treatment can be harmful to the local ecosystem as it eventually ends up in our lakes, rivers, streams, and wetlands. High levels of salt in waterways pollutes water supplies and is harmful to fish and other aquatic life. Once salt is in our waterways, it does not break down.

Figure 12-6: Sweeping leaves off a shared use path. (Source: City of Brooklyn Center, MN)

Figure 12-7: Anti-icing spray after it has been applied to a buffered bike lane



Timing of snow and ice removal efforts is also an important consideration. Sometimes winter precipitation begins with rain, and with a subsequent drop in temperature, ends with ice and/or snow. Cold air often follows winter precipitation, freezing liquid into ice on a walkway or bikeway. To achieve bare pavement in these scenarios, keep the following in mind:

- If rain falls before ice or snow, spreading salt is ill-advised because rain will wash it away. Rain can also push salt into storm sewers and bodies of water, causing unnecessary harm to the water supply.
- If rain and snow has turned to slush, remove the combination from walkways and bikeways before the temperature falls very far below freezing. Otherwise this precipitation will stay frozen in place as long as sub-freezing temperatures persist.

12.4.2. Equipment

Equipment for maintaining walkways and bikeways varies widely, from snow shovels to plows attached to pick-up trucks (see Figure 12-8). Operators also vary, from pedestrians and tractor operators to licensed drivers. Unlike roads, walkways, and separated bikeways (i.e., shared use path, side paths, separated bike lanes) are narrow facilities that may require smaller vehicles and lighter maintenance vehicles.

Figure 12-8: Variety of Maintenance Vehicles

Pickup truck with plow
Approximate Width: 8.5 ft./2.6 meters
Walkway/Bikeway Facility Types: Trails, side paths, 2-way separated bike lanes

Skid loader with snow blower
Approximate Width: 4 ft./1.2 meters
Walkway/Bikeway Facility Types: Walkways, trails, side paths, 2-way separated bike lanes, 1-way separated bike lanes

Miniature tractor with snow blower
Approximate Width: 4 ft./1.2 meters

Lawn mower tractor (converted to winter maintenance vehicle) with broom

Maintenance vehicle attachments such as plows, blowers, and brooms are vital pieces of winter equipment. Plows may be attached to many different types of vehicles and are used for pushing aside snowfalls of about 2 inches or more. Blowers and brooms are attached to smaller pieces of equipment. Blowers move large snowfalls (6 inches or more) and are also routinely used to move windrows, which are compacted piles of snow left over from road plows. Brooms are used to achieve a bare pavement surface and are typically used for snowfalls of 2 inches or less. Brooms may also be used to achieve bare pavement after plows or blowers have passed. Salt and sand spreaders may also be attached to maintenance vehicles.

12.4.3. Design

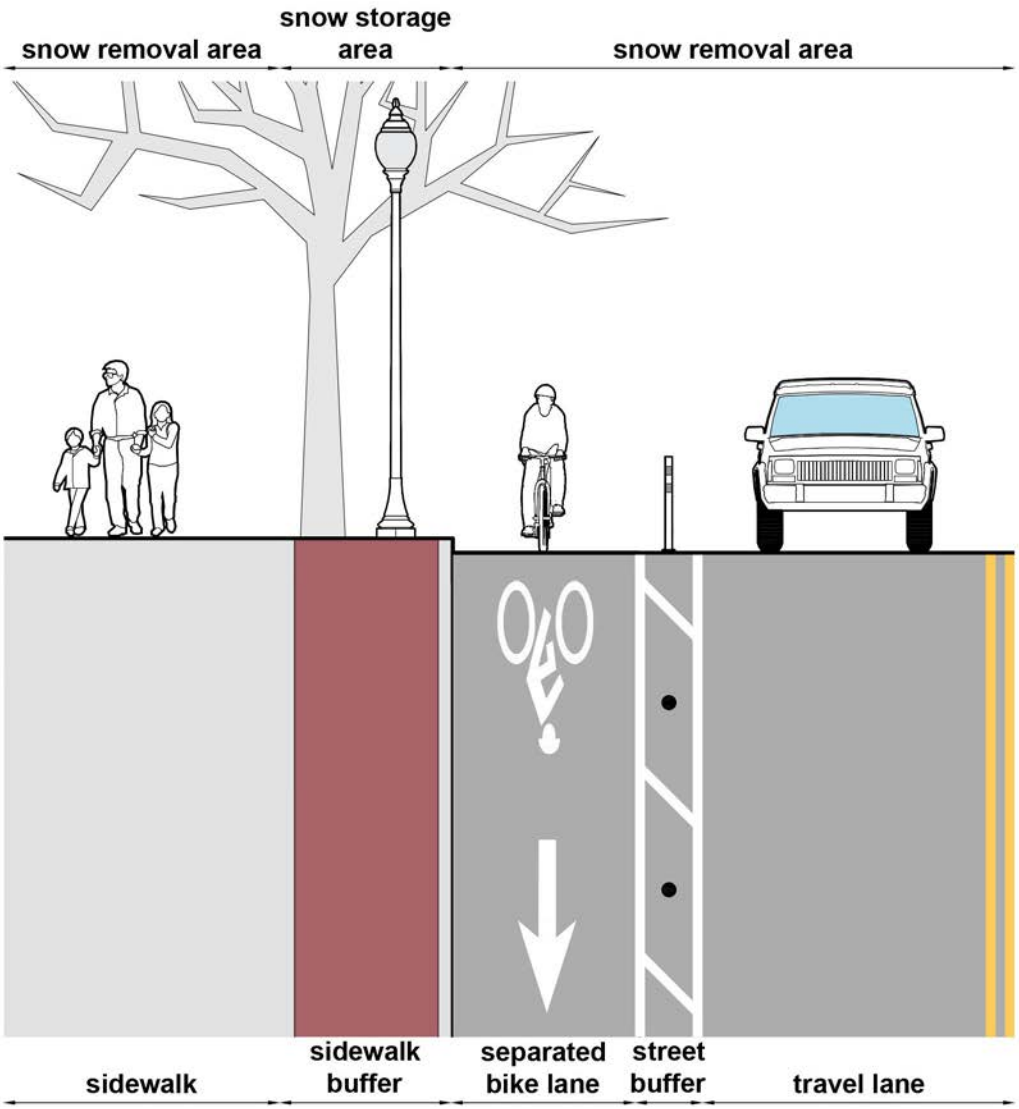
Several preventative measures can be taken during the design phase of a project to make winter walking and bicycling more feasible. Through careful design, walkways and bikeways can be engineered to avoid issues such as poorly drained facilities becoming icy and slippery because of the freeze/thaw cycle that often follows a winter precipitation event. As shown in Figure 12-9, designers should ensure that the areas next to the bikeway or walkway are graded away from the walking or biking surface, and that adequate drainage infrastructure should be provided to prevent standing water. For maintenance considerations for the placement of vertical elements in the street buffer along separated bicycle lanes, see Section 6.3.7.

Whenever possible, curb ramps should be located at the high point of an intersection to avoid standing water, and if this isn't possible, ADA compliant storm drain grates should be provided immediately up-hill from the curb ramps.

When possible, snow should be stored in the space between a road and a sidewalk or shared use path. The dimensions will depend upon the given community's climate, but typically these areas range from 4 ft. to 8 ft. in width. Where there is no space for snow storage, designers should consult with the jurisdiction's maintenance staff to make plans to address snow storage or off-site removal.

Several communities have retrofitted separated bike lanes that are located at street-level between existing curbs. When these facilities are located down-slope from the crown of a road, snow often melts and re-freezes into icy patches across bike lanes. To prevent this from occurring, snow should be removed from between the travel lanes and bike lanes instead of using this space for snow storage. The preferred long-term solution is to redesign the street to drain snowmelt away from separated bike lanes as shown in Section 6.3.7 - Drainage.

Figure 12-9: Removing snow from the buffer zone prevents snowmelt from refreezing across a separated bike lane



12.4.4. Transit stops

Transit stops may see high amounts of foot traffic in winter, making snow and ice removal on nearby walkways critical. Good winter maintenance near transit stops improves safety by keeping pedestrians out of the street and other dangerous areas. The clearing of snow at transit stops and on the walkways used to access transit stops is essential for maintaining access and is required to maintain ADA compliance.

Each community and agency should develop a well-defined understanding of who is responsible for maintaining transit stops. The responsible party may be state or municipal crews, transit agency crews, or adjacent property owners. While some communities have volunteer programs[3], the most important principle is providing consistent and reliable maintenance that allows transit users to walk to and from their stops.

12.5 Additional Resources

The following resources provide information about the importance of active transportation facility maintenance:

- **Cycling in Cities Opinion Survey**[4] – for data about how factors like routes with ice/snow, glass/debris, and potholes/uneven paving deter adult bicyclists.
- **Severity of Urban Cycling Injuries and the Relationship with Personal, Trip, Route and Crash Characteristics**[5] – to understand the role that collisions with potholes, rocks, roots, leaves, and ice play in emergency room visits at hospitals.
- **Winter Maintenance Resource Guide**[6] – for answers to questions like, "Do people walk and bike in snowy and icy conditions?", "Why do people walk and bike in winter?", "Will more people walk and bike if infrastructure is clear of snow and ice?", and "Does the Americans with Disabilities Act (ADA) require snow removal on walkways?"

Chapter 12 Endnotes

1 https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa13037/
2 https://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa13037/
3 http://adopt-a-stop.org/
4 https://cyclingincities-spph.sites.olt.ubc.ca/files/2012/08/OpinionSurveyBrochure.pdf
5 https://bmjopen.bmj.com/content/bmjopen/5/1/e006654.full.pdf
6 https://tooledesign.com/insights/2019/12/winter-maintenance-resource-guide/

OHIO DEPARTMENT OF TRANSPORTATION

ODOT MULTIMODAL DESIGN GUIDE

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